Popular Astronomy

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Charles Hayden

1870-1937

Charles Hayden was not an astronomer, professional or amateur, but he did love the stars and was greatly moved by the beauty of the night sky. In presenting as his gift the two great instruments of the Hayden Planetarium (the Zeiss projection planetarium and the Copernican model of the solar system) he made available to the people and the guests of New York City a priceless treasure—clear skies and good seeing, with the stars shining like myriads of diamonds overhead.

While Mr. Hayden did not himself actually contribute to astronomical science, his generous gift will undoubtedly have far-reaching effects in interesting the uninitiated in the study of astronomy. Who can tell when some young Copernicus or wondering Galileo may spend a chance hour beneath the starry sky of the Planetarium dome, and from that accidental beginning move on into greater and wider fields of knowledge for the glory of science and mankind.

—Marian Lockwood.

Tycho Brahe's Island

By CHARLES D. HUMBERD, M. D.

In the late 16th century the astronomical center of the world was the little Danish island of Hveen, in The Sound which connects the Baltic Sea with Cattegat and separates eastern Denmark from southern Sweden. On this island, in the most elaborately equipped observatories known to pre-telescopic days, the able Tycho Brahe (1546-1601) and his corps of numerous paid assistants, practiced observers and computers, and printers, lived and worked from 1576 to 1597, under the patronage of Frederick II of Denmark and the regency which succeeded this king. The labors were made with a view of accumulating a mass of accurate celestial observations by means of which it would be possible to effect the reform of Astronomy that was so imperatively demanded. Famous in those years, visited by scientists and royalty and nobility, the name of the island received an added lustre when the bulky records of those observations were searched and studied by the immortal Kepler, a few years later, and Kepler's Laws, the foundation stones of our whole system of dynamical Astronomy, were published. In truth, Tycho had given Kepler a place on which to stand, and Kepler had moved the world. In enormous strides Astronomy then went on to dazzling heights; Hveen soon returned to its former obscurity, but the residency of Tycho conferred on it an imperishable fame in Astronomy's history.

Tycho himself drew a map of Hveen; it was printed in his *Epistolarum Astronomicarum Libri,* Uraniburg, 1596, 4to., p. 264, and in his *Astronomiae Instauratae Mechanica,* Wandesburg, 1598, folio I.2. A smaller copy of Tycho's map adorns the frontispiece of Kepler's *Tabulae Rudolphinae,* Ulm, 1628, folio.

Dr. J. L. E. Dreyer's erudite and scholarly book on "Tycho Brahe, A Picture of Scientific Life and Work in the 16th Century," Edinburgh, 1890, 8vo., reproduces, page 90, an early map of Hveen from Blaeu's Grand Atlas of 1663. In a footnote on this page he writes: "I possess another large map with one page letterpress on the back, 'Topographia Insulae Huenae in Celebri Porthmo Regni Daniae quem vulgo Oersunt uocant, Effigiata Coloniae, 1586.' I believe it belongs to Braunii Theatrum Urbium. There are very few details on it, and the coastline is very incorrect, but the plans and views of Uraniborg in the corners of the map, and the descriptive letterpress on the back, are of value, as they contain some particulars not to be found elsewhere, and the author has evidently got reliable information, probably from A. S. Vedel, who is known to have contributed to the work." But Dr. Dreyer rather disappointingly did not make full use of this plate or text.

I bought this rare map recently from a Viennese bookseller for the proverbial song, and it is reproduced, much reduced, in the accompany-

ing illustration. The original is a curious combination of chart, diagram, and bird's eye view; it is neatly colored, by hand, and measures 18 15/16 by 13 3/8 inches, the page size being 20 15/16 by 15 7/8 inches. The legends in the corners of the map and the printed description which covers half of its back are in Latin; I have kept as near to the spirit of the original as possible in the following translation:

Topography of the Island of Hveen, situated in the Kingdom of Denmark's famous Sound commonly called Oersundt, on which is the castle called Uraniburg, well stocked with many elaborate astronomical instruments of varied and precise use, built to the honor and inception of this great science by the Danish noble, Tycho Brahe, Lord of Knudsdrup, about the year 1580.

The center of the island, where the castle stands, has the Pole elevated 55 or 54½ degrees, and is east about 37 degrees (*reckoned from Cape Verde Islands*). Its circumference is 8160 major paces which, assuming each pace to be 5 feet, equals about 2 smaller German miles. Since the island lies in the most frequented strait of the whole realm, through which many ships pass from the eastern (*Baltic*) to the western (*North*) Sea, and *vice versa,* in a beautiful prospect, it looks upon some of the principal cities of the kingdom in the neighborhood: in Zealand (*Denmark*), Copenhagen, the capitol of the kingdom, famous for its Royal Academy and its commerce, 3 miles distant towards Libanotom; Helsingor where the passing ships pay toll; and the castle called Kronberg, lately and magnificently built by King Frederick II two miles to the northwest. The same distance directly north and on the shore of Scania (*Sweden*) can be seen Helsingborg; in this country also is Landskronia at least a mile towards the southeast; Lund, though it is not a seaside town, can be seen from here, 4 miles distant towards Messeurum. But Malmo, 5 miles away, is in sight of Upophaenicis. (*All of the distances are much underestimated.*) These cities in the neighborhood can be seen from the island, and since it is quite high, it can likewise be seen from them. Although it is not very large no part of it is idle or unproductive; it is fruitful, and abounds in draft-animals, and it supports deer, hares, rabbits, and partridges in great number, and fish around about it; in a word it is very serviceable. It has a thicket of hazel shrubs, none of whose nuts are infested with worms; nor does the place suffer from mice. It was noted for 4 castles at the time when it was inhabited by the posterity of the giant Hvenella, from whom the island is believed to have derived its name, among whom are mentioned Hugh and Grunhilda, famous among the Germans in the History of Heroes. The names of the castles are still recounted: Synderburg which was situated on the south shore, while Nordburg held the opposite region in the north; Karhecidia looked towards the southeast while Hamera faced the northeast. The foundations of the 4 castles can still be seen, but there is nothing else left of their ruins. Although the island rises rather high in the midst of salt-water, nevertheless it has several

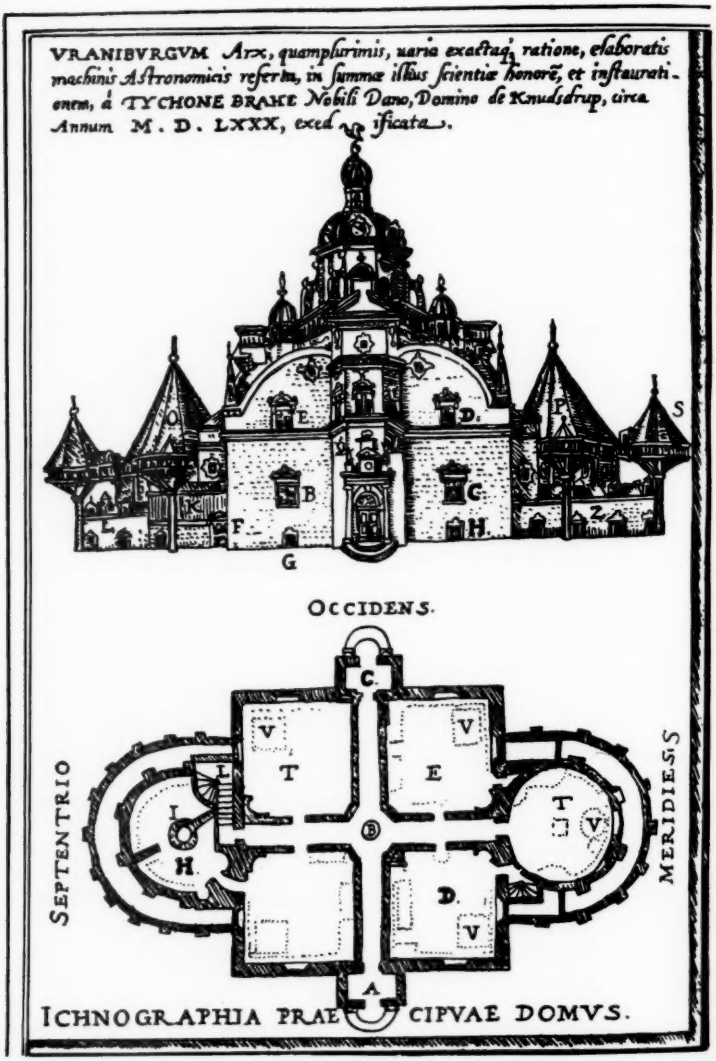
VRANIBVRGVM Arx, quamplurimis, uaria exactaq; ratione, elaboratis machinis Astronomicis referta, in summæ illius scientiæ honorē, et instauratiōnem, à TYCHONE BRAHE Nobili Dano, Domino de Knudstrup, circa Annum M. D. LXXX, exed ificata.
OCCIDENS.
SEPTENTRIO
MERIDIES.
ORIENS.
ICHNOGRAPHIA PRAE CIPVAE DOMVS.

FIGURE 1. INSERT (ORIGINAL SIZE) IN UPPER LEFT CORNER OF FIGURE 2.

Uraniburg. The castle, well stocked with very many elaborate astronomical instruments of varied and exact use built unto the honor and inception of this high science by Tycho Brahe, Lord of Knudsdrup, about the year 1580.

West
North South
East

Ground plan of the principal building.

streams and springs of sweet water. There is one spring that the rigor of winter never freezes, which is something most rare in these regions.

Front view of the castle Uraniburg on the island of Hveen in the Danish Sound, erected for the sake of Astronomy by the decree of the great and most powerful King Frederick II, built by Tycho Brahe, Lord of Knudsdrup. Explanation of the exterior of the main building (Figure 1):*

A. East door composed of Ionic and Doric work.
B. Winter dining-room.
F. Foundation stone which was laid by the French ambassador, the eminent Lord Charles Danzaeus.
G. and H. Windows of the underground rooms.
C. Guest chamber. Towards the west are 2 like this one.
M. Round museum, with the library and the large bronze globe whose diameter is 6 feet.
K. Aviary, corresponding to the one on the west side.
L. Circular underground chemical laboratory, containing 16 different furnaces, for the Paracelsian art (medicine).
I. Aperture through which live coals are discharged for studies in pyronomics (chemistry).
Z. Cell for storing wood for winter use.
X. Kitchen.
D. The King's red room.
a. Octagonal yellow room.
E. The Queen's blue room. On the west side, corresponding to these last three, is the great summer dining-room, decorated in green, from which all ships, from both the eastern and the western sea, plying to and fro through the Sound, can be seen in a pleasant view.
X. Windows of the upper floor.
O. The great south observatory, containing 6 huge astronomical instruments.
P. Revolving globe (*pillar?*) upon which instruments are placed when the distances of the stars are being observed. A like room corresponds to this on the west.
Q. Octagonal room in which is situated the above-mentioned globe.
N. The lesser south observatory, containing large equatorial armillaria.
VV. Stairs leading down to the laboratory and up to the observatory.
R. Main north observatory, containing 4 astronomical instruments.
S. Smaller north observatory, containing other large equatorial armillaria.
T. Another revolving globe used for mounting instruments; a similar globe is located on the east side.
V. The place where the great globe itself is situated.
e. The upper octagonal chamber, just below the highest point of the building, from which the view is open on all sides, and which has around the roof a parade called a Gallery.
yy. Octagonal structure in which there are 4 carved statues, representing the seasons of the year; by a hydraulic contrivance they are turned about at will, and each one lifts up three waters (*jets?*).
((. Six flues ending in one towards the south, and 6 others towards the north, in which all flues of the whole building individually unite.
N. Place for the clock which sounds the hours by means of a bell that hangs above in S.
λ. The Pegasus, showing whence the wind blows; when it is turned about it shows, by means of a movable indicator under the ceiling of the main octagonal chamber, all the winds just as they blow every day, and at any hour they are manifested under the same ceiling by means of another indicator revolving on the same center. (*Presumably one indicator showed the direction and the other the velocity of the wind.*)

*Unfortunately some of the identification marks in the following explanations are illegible on the scale of the illustrations as given here.

This then is the exterior description of the building as it appears to those looking from the east; the west side corresponds in all details, just as the north and south elevations are alike in everything.

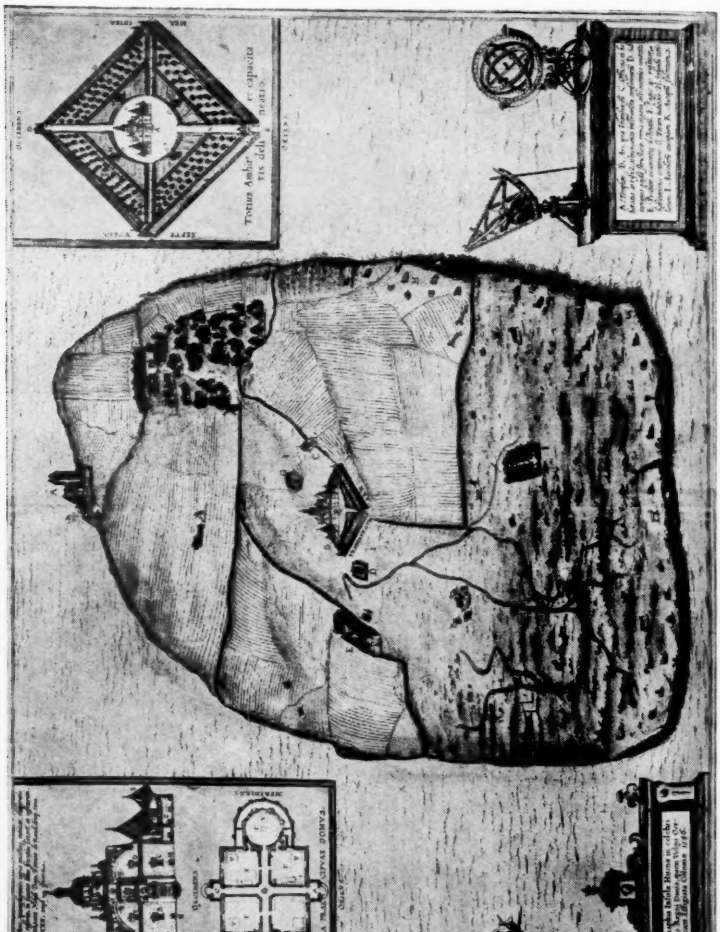

FIGURE 2. TYCHO BRAHE'S ISLAND, 1586

Topography of the island of Hveen in the Kingdom of Denmark's famous Sound which is commonly called Oersundt. Drawn at Cologne, 1586.

West
North South
Sketch of the entire surroundings and lay-out. **East.**

A. Church.
B. The castle of Uraniburg.
C. Workshop and dwelling of the artificers who make the astronomical instruments.
D. Partially underground structure, containing 3 astronomical instruments.
E. Manor for the steward.
F. Village containing the houses of 40 peasants.
G. Judicial court.
H. Hazel thicket.
I. Snare for small birds.
K. Falcon snare.

EXPLANATION OF THE GROUND PLAN (FIGURE 1).

A. Eastern entrance.
C. Western entrance.
θ. Four halls meeting at right angles.
B. Fountain turning a waterwheel which throws out water in different directions.
D. Winter dining-room.
E. F. G. Guests chambers.
L. Main stairs by which one ascends to the upper floor.
H. Kitchen.
I. Pantry.
K. Well, 40 ells (*fathoms*) deep, serving the hydraulic contrivance, and distributing water to every room of the whole building by means of pipes.
M. Space for storing kindling.
O. Steps to the underground pantry.
S. Space above the laboratory, where coals are thrown into the furnaces.
P. Smaller stairs leading from the laboratory to the observatory.
R. Aviary towards the west.
Q. Another aviary in the east in which the birds sing while flying to and fro among small trees.
T. Library.
VV. The large brazen globe.
4. Flues.
V. Tables.
Y. Couches.
N. Secret places.

All things in the whole lay-out are corresponding and equal to one another, so that the four chambers are of the same size, likewise the towers with the parades belonging to each, and also the portico and the halls dividing the rooms crosswise mutually preserve the same size. Therefore everything, whether viewed in the ground plan or the exterior view, has that proportion of size, the base of which is to be considered square with 50 feet to each side.

EXPLANATION OF THE SKETCH OF THE WHOLE LAY-OUT (FIGURE 2).

A. Principal building, constructed in the very middle of the whole lay-out, the four sides making a perfect square, most exactly turned to the 4 directions of the world, so that the 2 towers look to the south and north, and the 2 doors to the east and west.
E. Eastern gate of rustic and Tuscan design.
D. Western gate decorated with the same kind of work. Beyond these two gates are kennels which house 2 large English watchdogs that announce visitors from all sides with their barking.
B. Printing shop, copying the plan of the larger building on a small scale.
C. Small house for servants; it also resembles the larger building in front, and has an underground prison.
F. Exterior view of the wall.
G. Interior view of the wall with its flat top where 2 can walk abreast.
N. Four paths towards the gates and the small buildings and running exactly through the 4 directions of the world.
O. Four wooden gates.
M. Arbor constructed in the garden for pleasantry.
L. Gardens of plants and flowers.

FIGURE 2. TYCHO BRAHE'S ISLAND, 1586

H. Gardens of 300 trees of various kinds.
I. Gambling table called Pilkentafel.
K. Gambling table for globules called Rolltafel.

This is a general description of the whole lay-out. It is enclosed by a square wall, each of whose sides is 300 feet long. The height of the wall from the foundation is 18 feet. Its thickness at the base is 14 feet, but at the top, where they walk, it is 9 feet through. The house itself is situated in the middle; it is exactly square and 40 feet on each side. (*The ground plan says 50 feet.*) The height of its walls is 50 feet; the round towers annexed on the south and north have a diameter of 20 feet, to which the outside parade adds 9 feet. The porticos, square below, on the east and west, are 14 feet on either side. The whole height of the building from the ground to the Pegasus is 70 feet. The complete building, though it is not evident, has underground vaults, the depth of these is 12 feet, but since they are subterranean they are not represented here.

Figure 1 is a full-sized reproduction of the insert in the upper left corner of the old map of Hveen, published in this paper as Figure 2, drawn at Cologne, 1586. Other than the authentic woodcuts published later in Tycho's own works, I know of no other contemporary views of Uraniburg. This drawing presents no important variations from Tycho's, except that the ground-plan shows somewhat of a mirror-image reversal from the similar diagram given by Tycho. Tycho's descriptions of the building and instruments are in his *Epistolarum Astronomicarum Libri,* Uraniburg, 1596, 4to., pp. 218 *et seq.*, and in his *Astronomiae Instauratae Mechanica,* Wandsburg, 1598, folio H.4 *et seq.*, and they are in almost verbatim agreement with the text which accompanies this map. Facsimiles of Tycho's woodcut are fairly common in astronomical literature; there is a convenient one on p. 133 of Arthur Berry's *A Short History of Astronomy,* London, 1898, 8vo. An imaginary view of Uraniburg is to be found in the *Historia Coelestis of Lucius Barrettus* (Albert Curtz), Augsburg, 1666, folio, and a similar early picturization, which, however, could not have been made from first-hand sources but which furnishes some architectural details, is in a small and neat woodcut at the heading of Article I of Picard's *Voyage d'Uranibourg, ou Observations Astronomiques faites en Dannemarck,* Paris, 1680, folio.

Uraniburg was erected in 1576-77; its construction was of brick, with red sandstone masonry. Vandalism and the failure to make repairs immediately desolated the building after Tycho left Hveen in 1597. Twenty-six years later it had been completely demolished; its bricks were used in the walls of a farmhouse.

POSTSCRIPT.

When the above paper was sent in to POPULAR ASTRONOMY, the Editor, Dr. Gingrich, commented on some similarity which he had noticed between this unknown cartographer's description of Uraniburg

and the lay-out of Monticello, historic old home of Thomas Jefferson, near Charlottesville, Virginia. This resemblance is of interest, for it seems possible to trace a decided guidance which Tycho's plans had upon the ideas back of Monticello's architecture. The floor plans of Monticello (Wilstach, P., *Jefferson and Monticello,* 5th ed., N. Y., 1935, page 101) suggest Uraniburg with an added grand hall in its centre, and Jefferson's wind-indicators, distant clock dials, varying floor levels, the passages and stairs, and elaborately planned gardens, all are reminiscent of the castle on Hveen. (*Wilstach, however, credits the plans of Monticello to an Italian influence.*) But Tycho was a working astronomer, Jefferson was a practical farmer, and each adapted his domicile to his daily mode of life and his great surfeit of retainers and guests.

However, rather than an architectural unit erected as a complete edifice, Monticello was more of a "development." Its construction began about 1769, and gradually grew during 30 years to the spacious mansion that is preserved today. During the growth there was a great deal of intervening alteration and rebuilding, much of the present structure having been built between 1795 and 1803 (Capen, O. B., *Country Homes of Famous Americans,* N. Y., 1905, pp. 145-154). Jefferson travelled in Europe from 1784 to 1789, and "came back with a note-book full of observations, suggestions, and diagrams, intended for use on the homestead on his return" (Nicolay, J. G., *Thomas Jefferson's Home,* The Century Magazine, Sept., 1887, Vol. 34, n.s. vol. 12, no. 5, pp. 643-653. See also Stockton, Frank R., *The Later Years of Monticello, idem,* pp. 654-658). We know of his interest in matters astronomical from his possession of "two long telescopes mounted on brass tripods," his surviving letters on Banneker's almanacs, and his perennial presidency of The American Philosophical Society.

Jefferson's personal library of 6,760 volumes was sold to the national government in 1814 for $23,950, to become the nucleus of our present Library of Congress at Washington, the original library of the legislative body having burned during that year. The Library's printed Catalogue, 1815, inventoried the books acquired from Jefferson, and no. 23 on page 116 lists a copy of "Tycho Brahe's *Opera.*" That copy is no longer in the Jefferson Collection of the Library, for four-fifths of Jefferson's books were burned in the Capitol's fire of 1851. The reprint of Tycho's *Astronomia Instaurata Progymnasmata* published by Ioannis Godofredi Schönvetter from Frankfort in 1648 bore the title of "*Opera Omnia*;" it is most likely the edition which Jefferson owned, for all of the other early issues of Tycho's texts have more specific titles. The present copy of the 1648 edition in the Rare Book Room of the Library of Congress was not Jefferson's; it is illustrated only with mathematical and astronomical diagrams, several fullpage cuts of astronomical instruments, and a female figure sitting in a chair delineating a constellation.

Barnard, Missouri.

On the Visibility of Lunar Appulses

By ALEXANDER POGO

Clouds interfered, in many parts of North America, with the observation of the penumbral lunar eclipse of 1936 December 28. Nevertheless, the reports which have reached me from observers located in the Atlantic, the Eastern, and the Central Standard Time zones furnish sufficient data for a preliminary discussion of the visibility of lunar appulses. I hereby express my thanks to these observers—and to those who took

TABLE I

SUMMARY OF DATA, LUNAR APPULSE OF 1936 DECEMBER 28

		U.T. h m	Magn. of phase	Immersion into effective penumbra
Computed first contact with penumbra		1 49		
Observed beginning of visibility	B =	2 53	—0.37	0.1
Closest approach to umbra	M =	3 49	—0.15	0.3
Observed ending of visibility	E =	4 30	—0.27	0.2
Computed last contact with penumbra		5 49		

Magnitude of eclipse = —0.15 (Moon's diameter = 1.0)

the trouble of informing me that clouds prevented them from making observations.

The majority of the observers reported that, at the time of the closest approach ($3^h\ 49^m$ U.T.), about one third of the moon's diameter was darkened; some observers estimated the fraction as one third to four

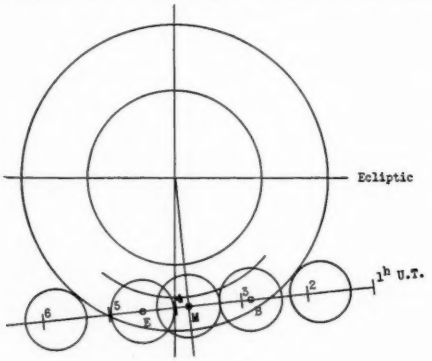

FIGURE 1

THE LUNAR APPULSE OF 1936 DECEMBER 28

tenths, others as four tenths of the diameter. This must be considered as a very satisfactory agreement, if one takes into consideration the elusive limits of the cone of the inner, optically effective penumbra; all the observations discussed in this paper were made with the unaided

eye.[1] The color of the darkened northern limb was described as "gray-black," "bluish," "light brown," "dusky, no color," etc.

The width of the optically effective penumbral ring may be considered as amounting to about one half of the width of the penumbral ring, or to about one third of the semidiameter of the umbra, or to about one fifth of the semidiameter of the penumbra. If the eclipsed moon is near perigee, the width of the effective penumbral ring would be about 15′ or 16′; near apogee, the width would be about 13′ or 14′. Observational data collected during the appulses of 1937 May 25 and 1940 April 22 ought to increase our knowledge of the limits of the effective penumbral cone. The diagram reproduced in Figure 1 shows an arc of the effective

TABLE II

CIRCUMSTANCES OF THE LUNAR APPULSE OF 1937 MAY 25

Moon enters penumbra	May 25^d 5^h 41^m U.T.
Closest approach to umbra	7 51
Moon leaves penumbra	10 1

Magnitude of the eclipse = —0.30 (Moon's diameter = 1.0)

penumbra which covers one third of the lunar diameter at the moment of closest approach.

The beginning and the ending of the visibility of an appulse occur when the limb of the moon encroaches to a certain extent on the outer layers of the effective penumbral cone. It is a simple task, even for an untrained observer, to estimate the fraction of the lunar diameter obscured at mid-appulse; it is rather difficult, even for a trained observer, to estimate the moments of the beginning and of the ending of the visibility of an appulse.

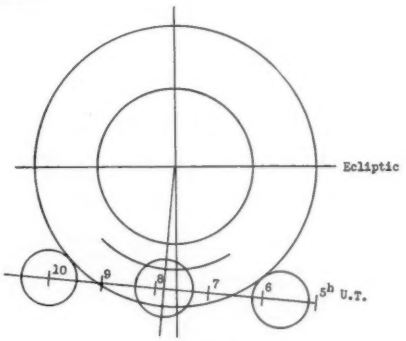

FIGURE 2

THE LUNAR APPULSE OF 1937 MAY 25

We shall designate by B′ the moment at which the beginning of the dark-

[1] In other words, without the aid of opera glasses, field glasses, etc.; glasses worn by some of the observers must be considered as (an artificial) part of their normal optical equipment.

ening of the limb was suspected by an observer of the appulse of 1936 December 28; the reported estimates of B′ varied between $2^h\ 15^m$ and $3^h\ 02^m$ U.T. The moment at which the beginning of the darkening was considered by an observer as unmistakable shall be designated by B″; the reported estimates of B″ varied between $2^h\ 45^m$ and $3^h\ 04^m$ U.T. The "duration of hesitation," B″-B′, varied between the extremes of 30^m and of 2^m (extremes responsible for the earliest B′ and for the latest B″, respectively); in the majority of cases the value of B″-B′ amounted to 10^m or 15^m, and this may be considered as the normal "duration of hesitation."

Similarly, we shall designate by E′ the moment at which the disappearing darkening was considered as barely visible; the reported estimates of E′ varied between $3^h\ 57^m$ and $4^h\ 50^m$ U.T. The moment at which the darkening became quite invisible shall be designated by E″; the reported estimates of E″ varied between $4^h\ 15^m$ and $4^h\ 54^m$ U.T. The "duration of hesitation," E″-E′, varied between the extremes of 18^m and of 9^m.

In assigning weights to the B″ and E′ data used as the observed times of the beginning and of the ending of the visibility of the appulse, I have taken into consideration the experience of the observer (when known to me), the reported transparency of the sky, and the "duration of hesitation." The weighted mean of the reported B″ data was adopted as B = $2^h\ 53^m$ U.T., the observed time of the beginning of the visibility, to the unaided eye, of the appulse of 1936 December 28; the negative magnitude corresponding to this phase of the appulse was —0.37. Similarly, the weighted mean of the reported E′ data was adopted as E = $4^h\ 30^m$ U.T., the observed time of the ending of the visibility of the appulse; the negative magnitude corresponding to this phase was —0.27. The positions of the moon at the moments B and E are shown in the diagram of Figure 1. The immersion of the moon into the effective penumbra amounted to about 0.1 at the moment B, and to about 0.2 at the moment E. A summary of the data concerning the appulse of 1936 December 28 will be found in Table I.

If we designate by M (= $3^h\ 49^m$ U.T.) the moment of closest approach, we have M-B > E-M. This inequality is not due to our method of finding B and E; if we subtracted, from B, one half of the "duration of hesitation," and if we added, to E, the same amount, the inequality would still remain. In the individual reports of the trained observers, we find, consistently, that M-B″ > E′-M. The chief causes of the inequality seem to be of a physiological and psychological nature; when an appulse of long duration approaches its end, the eye of the tired observer is less sensitive to the contrast between the elusive darkening of the limb and the fully illuminated disc of the moon; it is easier to notice the early stages of an increasing darkening than the last traces of a disappearing dimming. In the case of appulses observed near the horizon, the variations of the absorption, at different altitudes, must be taken into consideration.

What is the limiting magnitude of a penumbral lunar eclipse which can be noticed by the average naked-eye observer? The duration of such an appulse being short, the fatigue of the observer is eliminated; on the other hand, the importance of the "duration of hesitation" is increased; the interval between the moments B and E is so short that the observer begins to lose the impression of darkening soon after this impression could be considered as unmistakable. It is probable that this implies an immersion of about 0.15 of the moon's diameter into the effective penumbra, or a distance between the umbra and the limb of about one third of the moon's diameter; in other words, the limiting negative magnitude of a lunar appulse barely visible to the unaided eye seems to be —0.33. A small appulse is more likely to be visible when the brilliant southern limb (near Tycho) is dimmed by the effective penumbra than in the case of an immersion of the northern limb (near Mare Frigoris).

The penumbral lunar eclipse of 1937 May 25 (Monday night, $11^h\ 51^m$ Pacific Standard Time; Tuesday morning, $1^h\ 51^m$ Central Standard Time) will offer us an opportunity to obtain additional data concerning the width of the effective penumbral ring and the visibility of appulses of short duration. The circumstances of this eclipse are summarized in Table II and are illustrated by the diagram reproduced in Figure 2. The moon passes apogee on May 24, about 13^h U.T., less than one day before the eclipse; the width of the effective penumbral ring shown on the diagram was assumed to be 13′; at mid-eclipse, the corresponding immersion of the northern limb into the effective penumbra would amount to 0.15 of the moon's diameter. The eclipsed moon will be in the zenith over a point in the Pacific Ocean, longitude 119° W, latitude 21° S.

I shall be grateful for information concerning the time of the beginning and of the ending of the visibility of the appulse to the unaided eye; an estimate of the fraction of the moon's diameter darkened at the moment of maximum phase is also desirable.

STUDY 33, DECK A
LIBRARY OF CONGRESS
WASHINGTON, D. C.

Drive for a Small Dome

By MORGAN CILLEY

An efficient drive for a small dome was recently installed in the observatory of Mr. Harry Footer of Cumberland, Maryland. It was designed by the master mechanic of the Footer plant and can be operated by the observer with a minimum of distraction. The dome is of aluminum, is 12 feet in diameter and houses a fine 5-inch Clark equatorial refractor.

The observatory below the dome is square, and, in one of the corners, a ¼-h.p. motor was mounted on one of the corner spandrels. A ¼-inch

plate 10 inches square was bolted to the spandrel and the motor hung from it. A worm on the motor shaft drives a gear on the ½-inch sprocket shaft giving a speed reduction of 20 to 1. The sprocket shaft passes up through the base plate and spandrel to the sprocket on a level with the base plates of the dome.

On these base plates, eight ⅛-inch plates were riveted and spaced equally. They were so shaped and bent that they keep the sprocket chain in place, which, bending and meshing inside them transmits the power to the dome. They are also so placed and shaped that they clear the sprocket gear as they pass.

A two-way switch on the equatorial pillar puts the control in easy reach of the observer and, since the sprocket drives an endless chain, the observer has no worry as to the direction in which he must move the dome; it can be continuous in one direction if he so desires and this, too, reduces somewhat the trouble with snow and ice. The device has been in use about two years and has given entire satisfaction.

Constellations

By D. F. BROCCHI

That the division of the sky in constellations is a matter of practical necessity is too well established a fact to require additional argument in its favor. Its importance has induced the International Astronomical Union to approve the undertaking of the laborious process of establishing definite boundary lines.

As the result of this work, accomplished by E. Delporte of the Uccle Observatory and described in "Report of Commission 3 of the I.A.U.," Cambridge University Press 1930, having been accepted by the Union at the Congress of Leyden in 1928, the confusion so often deplored in the past has come to an end, the constellations being now definitely outlined by arcs of right ascension and declination referred to the epoch 1875.0.

Even so the system of the constellations is not free from objectionable features, among which may be mentioned lack of compactness of form in some cases, the worst being that of Hydra, 108 degrees in length with an average width of 12 degrees.

Not less conspicuous is the disparity in extent, reaching a maximum ratio of 19 to 1 between Hydra and Crux, illustrated in Figure 1.

It seems very doubtful that a satisfactory reason can be advanced to justify the retention as one constellation of the two sections of Serpens, one bordering on the galactic equator, the other half way to the galactic pole.

A time will come when precession from 1875 can no longer be applied by the simple method of straight line functions with any reasonable degree of accuracy, not to mention the added complication of pro-

per motion; a time when constellation boundaries on star maps will consist of all sorts of curves intersecting equatorial coördinates at all sorts of angles; a time when proper motion will have carried prominent stars across constellation boundaries.

Fortunately such time is comparatively remote, and need cause no worry for some years to come; so in spite of objections, it must be admitted that the constellations as now outlined are very much of an improvement on what they have been, and we must trust the astronomers of the future to find a way out of difficulties, when difficulties arise.

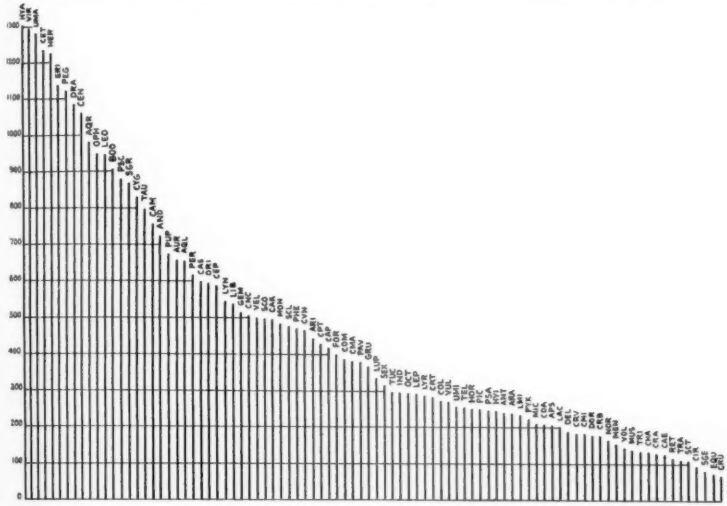

FIGURE 1
AREA OF CONSTELLATIONS IN SQUARE DEGREES

Such being the case, it has seemed worth while to ascertain the spherical area of the constellations in square degrees and the position of the geometrical center, as matters of general interest and perhaps, it is to be hoped, to serve some useful purpose. Application to a definite purpose has been attempted, but owing to unavoidable restrictions, the results are of doubtful value, as will be shown below.

The process of calculation for the area consists in subdividing the constellation in zonal sectors by producing the boundary meridians across it and computing the area of each sector by the formula

$$s = (90/\pi)\, m \sin \tfrac{1}{2}(D - d) \cos \tfrac{1}{2}(D + d)$$

where m is the difference in right ascension in minutes of time and D and d the limiting declinations in degrees.

The formula has been derived from the general equation for the area of surfaces of revolution about the Y axis.

$$s = 2\pi \int_a^b x\left[1 + \left(\frac{dx}{dy}\right)^2\right]^{\frac{1}{2}} dy$$

If the generating curve is a circular arc with center at the origin, this equation becomes

$$s = 2\pi rh$$

where h is the height of the zone, and when applied to the celestial sphere, can be expressed by

$$h = r \sin D - r \sin d = 2r \cos \tfrac{1}{2}(D + d) \sin \tfrac{1}{2}(D - d)$$

The area being required in square degrees,

$$r = 180/\pi$$

and the rest of the transformation is a simple matter of algebraic reduction.

The calculation has been carried to the third decimal place by the use of 7 place logarithms. Owing to the large average number of sectors, the last digit in the area of the constellation may be in error and possibly even the second in some cases, but the error can not exceed 0.01.

The two sections of Serpens are listed separately as Caput (Cpt) and Cauda (Cda) in the table and diagrams, in case it should be decided at some future time to consider them as two separate constellations.

It was decided to omit the lengthy calculation required to ascertain the position of the geometrical center to a high degree of accuracy, and to adopt a combination of graphical and mechanical methods. Each constellation was drawn to fairly large scale on monoconic projection with the projection cone tangent to the sphere at the mean declination in order to distribute the distortion symmetrically over the entire surface. Cardboard patterns were cut accordingly and balanced on a sharp straight edge in several directions to locate the center of gravity.

The results are given below in tabular form with the following arrangement: 1. Abbreviated name of constellation. As noted elsewhere, the abbreviations Cpt and Cda designate the two sections of Serpens. 2. Area in square degrees. The total of this column is 41252.946, showing an error of —0.016 when compared with the area of the sphere, which is 41252.962. 3 and 4. Approximate position of geometrical center referred to galactic coördinates, assuming the north galactic pole at $12^h\,40^m$, $+28°$ for the epoch 1900.0. 5. Number of stars to minimum magnitude 6.54 according to Revised Harvard Photometry. Components of multiple stars are counted separately. Variable stars are included according to mean magnitude, excepting those of the R CrB type, included according to maximum. The total of this column is 8611. 6. Star density, or number of stars of preceding column per 10 square degrees of area.

Const.	Area	Long.	Lat.	Stars	Dens.
And	722.278	88° 39′	—22° 20′	164	2.27
Ant	238.900	235 53	+17 51	43	1.80
Aps	206.327	281 28	—18 8	33	1.60
Aql	652.472	7 41	—10 28	121	1.85
Aqr	979.854	16 47	—52 47	163	1.66

Const.	Area	Long.	Lat.	Stars	Dens.
Ara	237.058	304 5	−10 19	61	2.57
Ari	441.395	122 47	−35 40	86	1.95
Aur	657.437	137 47	+ 8 12	151	2.30
Boo	906.830	11 21	+66 10	150	1.65
Cae	124.864	208 16	−39 36	19	1.52
Cam	756.827	109 7	+20 57	147	1.94
Cap	413.947	356 29	−37 38	86	2.08
Car	494.184	246 15	−11 56	197	3.99
Cas	598.407	91 32	− 0 14	151	2.52
Cda	208.445	342 13	+ 8 10	39	1.87
Cen	1060.421	273 9	+16 43	274	2.58
Cep	587.787	79 7	+12 38	142	2.42
Cet	1231.410	125 10	−68 24	170	1.38
Cha	131.592	264 25	−18 40	33	2.51
Cir	93.353	283 11	− 3 34	36	3.86
CMa	380.118	199 46	− 9 17	148	3.89
CMi	183.366	180 18	+13 53	41	2.24
Cnc	505.872	173 53	+33 23	101	2.00
Col	270.184	208 7	−26 56	73	2.70
Com	386.475	262 57	+85 16	64	1.66
Cpt	428.484	345 44	+45 35	70	1.63
CrA	127.696	321 19	−16 2	42	3.29
CrB	178.710	18 49	+49 43	36	2.01
Crt	282.398	242 16	+42 39	31	1.10
Cru	68.447	267 18	+ 2 39	45	6.57
Crv	183.802	262 40	+44 19	27	1.47
CVn	465.193	71 46	+76 11	57	1.23
Cyg	803.982	49 19	+ 0 45	267	3.32
Del	188.549	24 46	−18 25	46	2.44
Dor	179.173	237 47	−36 8	31	1.73
Dra	1082.951	66 11	+35 6	211	1.95
Equ	71.641	25 32	−27 32	16	2.23
Eri	1137.918	181 43	−49 4	185	1.63
For	397.502	196 34	−63 49	62	1.56
Gem	513.762	160 44	+15 7	120	2.34
Gru	365.513	316 51	−57 33	56	1.53
Her	1225.146	18 33	+31 5	245	2.00
Hor	248.885	233 26	−51 53	32	1.29
Hya	1302.842	230 14	+33 21	228	1.75
Hyi	243.035	259 49	−43 41	31	1.28
Ind	294.006	303 26	−43 39	38	1.29
Lac	200.688	65 47	−11 20	62	3.09
Leo	946.963	196 2	+58 37	123	1.30
Lep	290.292	189 52	−24 24	74	2.55
Lib	538.051	314 6	+34 36	81	1.51
LMi	231.955	158 56	+58 13	36	1.55
Lup	333.682	297 29	+12 19	118	3.54
Lyn	545.385	139 49	+32 27	97	1.78
Lyr	286.475	33 32	+15 7	78	2.72
Men	153.484	256 2	−30 43	25	1.63
Mic	209.513	334 25	−41 3	39	1.86
Mon	481.569	183 42	+ 1 48	148	3.07
Mus	138.355	268 40	− 7 10	57	4.12
Nor	165.290	297 59	+ 0 4	39	2.36
Oct	291.046	274 54	+30 20	62	2.13
Oph	948.337	343 48	+16 45	173	1.82
Ori	594.121	166 44	−13 25	208	3.50
Pav	377.666	297 32	−29 16	77	2.04
Peg	1120.793	53 17	−34 17	169	1.51
Per	614.997	118 28	− 9 0	157	2.55
Phe	469.319	270 28	−69 30	67	1.43
Pic	246.740	226 47	−32 3	48	1.95
PsA	245.375	344 52	−57 6	44	1.79

Const.	Area	Long.	Lat.	Stars	Dens.
Psc	889.415	83 7	−51 28	132	1.48
Pup	673.434	215 4	− 4 51	252	3.74
Pyx	220.833	220 13	+11 10	45	2.04
Ret	113.936	240 18	−44 16	23	2.02
Scl	474.764	307 55	−83 23	52	1.10
Sco	496.784	317 11	+ 8 0	165	3.32
Sct	109.114	350 18	− 2 57	28	2.57
Sex	313.515	213 8	+43 0	40	1.28
Sge	79.923	22 46	− 3 9	29	3.63
Sgr	867.433	337 26	−16 41	199	2.29
Tau	797.250	145 9	−22 18	219	2.75
Tel	251.511	313 21	−25 46	48	1.91
TrA	109.977	288 9	−10 19	32	2.91
Tri	131.847	109 9	−27 35	24	1.82
Tuc	294.556	279 24	−51 28	45	1.53
UMa	1279.660	117 53	+56 52	221	1.73
UMi	255.865	80 15	+38 8	42	1.64
Vel	499.648	240 9	+ 3 28	194	3.88
Vir	1294.428	285 1	+59 14	164	1.27
Vol	141.354	248 54	−20 19	31	2.19
Vul	268.165	32 23	− 6 31	75	2.80

Figure 1 is self explanatory, being inserted for visual comparison of the areas with one another.

Figure 2 is for the purpose of comparing star density with galactic polar distance. While the general tendency indicates conformity, it

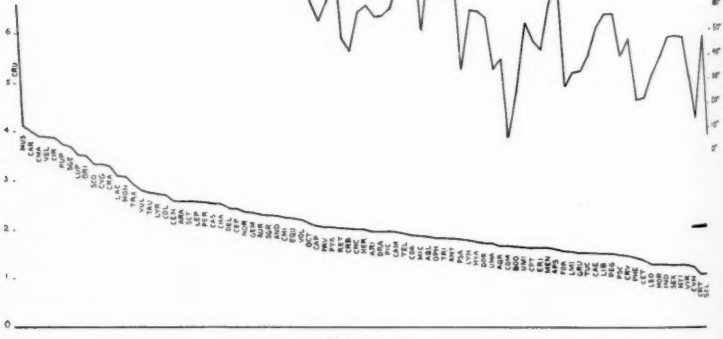

FIGURE 2
STAR DENSITY COMPARED WITH GALACTIC POLAR DISTANCE

fails for individual constellations, as might be expected from the small number of stars involved compared with all the stars of the galaxy. A more satisfactory result would undoubtedly be obtained by including stars to a fainter limit of magnitude. Unfortunately some of these are omitted in Revised Harvard Photometry, and in other catalogues, where such stars are listed, the magnitudes are not reliable.

The Forty Nearest Stars

By ROY K. MARSHALL

In POPULAR ASTRONOMY, **38**, 17 (1930), Dr. van de Kamp gave a list of 36 stars within 5 parsecs (about 16 light years) of the sun, to which he added a supplementary list of a few stars which might prove to be included in the former list when better values of the parallaxes were obtained. The appearance of a new general catalogue of parallaxes compiled by Yale astronomers early in 1935 provides the most up-to-date material from which to compile a revised list of the nearby stars.

The new table includes 40 stars, in spite of the fact that two of van de Kamp's stars have been omitted; six stars, then, have been added to the earlier list.

In Table I are given the forty stars which, on the basis of their trigonometric parallaxes listed in the new Yale general catalogue of parallaxes (with two exceptions, taken over from the earlier list), are within 5 parsecs of the sun. The Yale number is given in the first column; following the columns giving the positions, apparent magnitudes, and spectral classes are three columns in which are tabulated the values of the trigonometric, spectroscopic, and dynamic parallaxes from the Yale catalogue; the letters "a," "b," "c" affixed to the dynamic parallaxes give some indication of the reliability of the determination; "a" indicates a determination from an orbit, "b" indicates that the value is a good one, "c" that it is only average. The next two columns give the annual proper motions and the tangential velocities derived from them, in kilometers per second. The column headed V includes the radial velocities, taken from Moore's general catalogue (*Lick Observatory Publications*, Vol. 18, 1932); this catalogue was also the source for the spectral classes and magnitudes, for the most part. The column headed S contains the space velocities of the stars with respect to the sun. S and V are in km. per second. M is, of course, the absolute magnitude.

Table II contains eleven stars which might be included in the first table, if spectroscopic or dynamic parallaxes were given weights equal to or superior to that given the trigonometric determinations. The two components of 70 Ophiuchi are almost certainly just on the borderline, but it is equally certain that the other nine stars are definitely beyond 5 parsecs.

Most of the values of the parallaxes have been changed in the five years elapsing between van de Kamp's list and the appearance of the 1935 edition of the Yale parallax catalogue, some of them by amounts sufficient to exclude them from this new list. The eleventh star in the 1930 list was BD —7°4003, with a parallax of 0″.331; the value for the parallax in the 1935 catalogue is only half this amount, however. The star with the Yale number 3188, included in the present Table II, was

TABLE I—PART 1

THE FORTY NEAREST STARS

No.	Star	R.A. h m	Decl. ° ′	Mag.	Sp.	Parallaxes—Trig.	Sp.	Dy.	
4304	Prox Cen*	14 22.8	−62 15	11	M	0″.762			
4344	α Cen A	14 32.8	−60 25	0.33	G_0	.756	0″.78	0″.78a	
	α Cen B			1.70	K_1				
5352	CC 1069	17 52.9	+ 4 25	9.7	M_4	.545	.40		
	Wolf 359**	10 51.6	+ 7 36	13.5	M_6e	.407			
3389	Lal 21185	10 57.9	+36 38	7.60	M_2	.388	.42		
2142	α CMa A	6 40.7	−16 35	−1.58	A_0	.373	.40	.40a	
	α CMa B			8.5	A_5				
	Innes' Star	11 12.0	−57 02	12		.340			
7405	CC 1445	23 37.0	+43 40	12	M_6	.314			
1036	ε Eri	3 28.2	− 9 48	3.81	K_1	.305	.29		
518	τ Cet	1 39.4	−16 28	3.65	G_7	.301	.29		
6558	61 Cyg A	21 02.4	+38 15	5.57	K_7	.299	.30	.35b	
	61 Cyg B			6.28	M_0				
2423	α CMi A	7 34.1	+ 5 29	0.48	F_5	.291	.34	.30a	
	α CMi B			14	F				
6849	ε Ind	21 55.7	−57 12	4.74	K_5	.288	.28		
71	Cin 25 A	0 12.7	+43 27	8.2	M_2	.284	.23		
	Cin 25 B			10.6	M_5				
5652	Cin 2456 A	18 41.7	+59 29	9.2	M_4	.282	.28	.23b	
	Cin 2456 B			9.7	M_5				
7213	Lac 9352	22 59.4	−36 26	7.44	M_2	.278	.26		
1630	Cin 675	5 07.7	−44 59	9.2	K_2	.262			
7020	Krue- 60A	22 24.4	+57 12	9.3	M_3	.258	.20	.22a	
	ger 60B			11	M_4				
6606	Lac 8760	21 11.4	−39 15	6.65	M_1	.257	.24		
4925	CC 995	16 24.7	−12 25	9.5	M_3	.255	.25		
228	CC 58	0 43.9	+ 4 55	12.3	F_3	.243			
7145	CC 1387	22 47.9	−14 47	9.5		.231			
5196	CC 1038	17 21.1	−46 47	9.4		.225			
7528	Cin 3161	23 59.5	−37 51	8.3	M_3	.222	.22		
3151	Grmbr 1618	10 05.3	+49 58	6.82	M_0	.220	.18		
5278	Cin 2354	17 37.0	+68 26	9.5	M_4	.213	.17		
5241	CC 1046	17 29.8	−44 14	10.0		.208			
6062	α Aql	19 45.9	+ 8 36	0.89	A_5	.208	.16		
7122	CC 1382	22 42.5	+43 49	10.2	M_5e	.207	.24		
6693	CC 1290	21 26.9	−49 26	8.6	Ma	.207			
1304	o^3 Eri A	4 10.7	− 7 49	4.48	K_0	.202	.22	.24a	
	o^3 Eri B			8.9	A				
	o^2 Eri C			10.8	M_6e				

*The value of S is computed on the assumption that V is the same as for 4344.
**The value of V, hence that of S, depends on measures of emission lines only.

TABLE II

POSSIBLE NEARBY STARS

No.	Star	R.A. h m	Decl. ° ′	Mag.	Sp.	Parallaxes—Trig.	Sp.	Dy.	μ	M
5405	70 Oph A	18 00.4	+ 2 31	4.28	K_0	0″.196	0″.20	0″.20a	1″.13	+ 5.7 1′
	70 Oph B			5.98	K_4					+ 7.4
3188	Cin 1244	10 14.2	+20 22	9.4	M_4e	.193	.21		0.49	+10.8 2′
4119	Cin 1786	13 40.7	+15 26	8.5	M_2	.191	.20		2.30	+ 9.9 3′
4440	Lal 27173A	14 51.6	−20 58	5.76	K_5	.172	.17	.20c	1.98	+ 6.9 4′
	Lal 27173B			8.9	M_2					+10.1
2917	Lal 18115A	9 07.6	+53 07	7.90	M_0	.162	.15	.21b	1.68	+ 8.9 4′
	Lal 18115B			8.01	M_0					+ 9.1
502	PGC 377A	1 36.0	−56 42	6.7	G_5	.161		.21a	0.29	+ 7.7 5′
	PGC 377B			6.8	G_5					+ 7.8
3400	Cin 1349	11 00.5	+44 02	8.6	M_2	.174	.20		4.52	+ 9.8 6′

*See opposite page.

TABLE I—PART 2

THE FORTY NEAREST STARS

No.	Star	μ	T	V	S	M	Remarks
4304	Prox Cen*	3″85	24		(32)	+15.4	Common proper mo-
4344	α Cen A	3.68	23	— 22.2	32	+ 4.7	[tion with 4344
	α Cen B					+ 6.1	Binary, period 80 yrs.
5352	CC 1069	10.30	90	—110	142	+13.7	Barnard's Star
	Wolf 359**	4.84	56	— 90	106	+16.5	Not in 1935 Yale Cata-
3389	Lal 21185	4.78	58	— 86.6	104	+10.5	PGC 2935 [logue
2142	α CMa A	1.32	17	— 7.5	18	+ 1.3	Sirius, binary, period
	α CMa B					+11.4	51 years
	Innes' Star	2.69	38			+14.7	Not in 1935 Yale Cat.
7405	CC 1445	1.82	27			+14.5	Ross 248
1036	ε Eri	0.92	14	+ 15.4	21	+ 6.2	PGC 814
518	τ Cet	1.92	30	— 16.2	34	+ 6.0	PGC 391
6558	61 Cyg A	5.20	82	[—65.1]	105	+ 8.0	Probably binary, very
	61 Cyg B			[—63.4]		+ 8.7	long period
2423	α CMi A	1.24	20	— 3.0	20	+ 2.8	Procyon, binary, period
	α CMi B					+16.3	40 years
6849	ε Ind	4.70	77	— 40.4	87	+ 7.0	PGC 5654
71	Cin 25 A	2.89	48	+ 7.6	49	+10.5	Groombridge 34A 39″
	Cin 25 B					+12.9	Groombridge 34B c.p.m.
5652	Cin 2456 A	2.31	39	[+0.2	39	+11.5	Σ 2398; Binary?
	Cin 2456 B			+7.2]		+12.0	
7213	Lac 9352	6.90	118	+ 10.1	118	+ 9.7	Cin 3014
1630	Cin 675	8.75	158	+242	289	+11.3	Kapteyn's Star
7020	Krueger 60A	0.87	16	— 24.4	29	+11.4	Binary, period
	Krueger 60B					+13.1	44 years
6606	Lac 8760	3.53	65	+ 22	69	+ 8.7	
4925	CC 995	1.21	22			+11.5	
228	CC 58	2.98	58	+238	245	+14.2	Wolf 28; van Maanen's
7145	CC 1387	1.12	23			+11.3	[star
5196	CC 1038	1.15	24			+11.2	
7528	Cin 3161	6.11	130	+ 24.0	133	+10.0	Cordoba 32416
3151	Grmbr 1618	1.45	31	— 27.2	41	+ 8.5	
5278	Cin 2354	1.33	30	— 17	34	+11.1	
5241	CC 1046	1.14	26			+11.6	
6062	α Aql	0.66	15	— 26.1	30	+ 2.5	Altair, PGC 5062
7122	CC 1382	0.84	19	+ 2	19	+11.8	
6693	CC 1290	0.78	18			+10.2	
1304	o^2 Eri A	4.08	96	— 42.4	105	+ 6.0	82″, c.p.m. with sys. BC
	o^2 Eri B					+10.4	Binary
	o^2 Eri C					+12.3	

REMARKS ON TABLE II

(1) Binary, period 88 years.

(2) McCormick trigonometric parallax 0″.200; Dearborn trigonometric parallax 0″.171.

(3) Lalande 25372. Trigonometric parallaxes range from 0″.229 (McCormick) to 0″.157 (Yerkes).

(4) Binary?

(5) Period 219 years.

(6) Lalande 21258. Trigonometric parallaxes range from 0″.181 to 0″.167, so this star is probably not within 5 parsecs, in spite of the value of the spectroscopic parallax given above.

the 36th star in van de Kamp's list, with a parallax of 0″.202. It is true that the spectroscopic parallax for this object is larger than some of those included in Table I, but the value of the trigonometric parallax should be reliable, and excludes the star from the first forty.

Certain other stars have been displaced from their old places, but have still been included in Table I. For example, star numbered 4925 has been moved from 9th to 27th place; star numbered 1630 has been moved from 12th to 23rd place.

Doubtless many of the deep red stars now being discovered will be included in the next tabulation of this type, if another period of five years elapses.

WILSON COLLEGE OBSERVATORY, CHAMBERSBURG, PENNSYLVANIA.

On An Apparent Displacement of the Meridian as a Function of the Lunar Hour Angle

By MAYNARD F. JORDAN

In view of the results obtained by Dr. Stetson[1] suggesting a correlation between the variation of latitude and the hour angle of the moon, it seemed desirable to investigate the possibility of a displacement of the meridian as a function of the moon's hour angle. The material best suited for such a study was obtained from two sources: The Washington-Paris Longitude Determination 1913-1914,[2] and The Wireless Time Signals Observed at Ottawa 1921-1926.[3]

The right ascensions of the 118 time stars used at Washington were obtained from the *Preliminary General Catalogue* of Boss for 1900. 1636 observations were made on seventy-four nights from October 28, 1913, to April 3, 1914. The stars observed each night were divided into one hour groups and the mean right ascension and mean observed clock correction t_o determined for each group. The lunar hour angle corresponding to the mean right ascension of each group was calculated. The adopted, or curve clock corrections, t_a, tabulated in the Washington data, were obtained from a smooth curve drawn through the points representing group means of the observed clock corrections.[4] A card catalogue was made up, each card containing the hour angle of the moon and the difference between the adopted and the observed clock correction to which value ten was added in order to make all the quantities positive. There were 408 cards making on the average four stars represented on each card. The cards were divided into twenty-four approximately equal groups arranged in such a way that each group repre-

[1] "On the variation of latitude with the moon's position," *Science*, January 4, 1929.

[2] "Determination of the longitude between Washington and Paris 1913-14." *Publications of the U. S. Naval Observatory*, Vol. IX.

[3] "Wireless time signals observed at Ottawa." *Publications of the Dominion Observatory*, Vol. XI.

[4] *Publications of the U. S. Naval Observatory*, Vol. IX.

sented a change of approximately one hour in the moon's hour angle. The mean hour angle and mean residual clock correction were determined for each group. The points on the curve were calculated from the hourly means by using the running means, taking three at a time.

The material obtained from the Dominion Observatory extended from 1921 to 1926 inclusive, and was treated in so far as possible like the Washington observations. Detailed information regarding these data was very kindly furnished by the Director of the Dominion Observatory. The star positions adopted at Ottawa up to the end of 1923 were obtained from Boss, and after that time Eichelberger's positions of clock

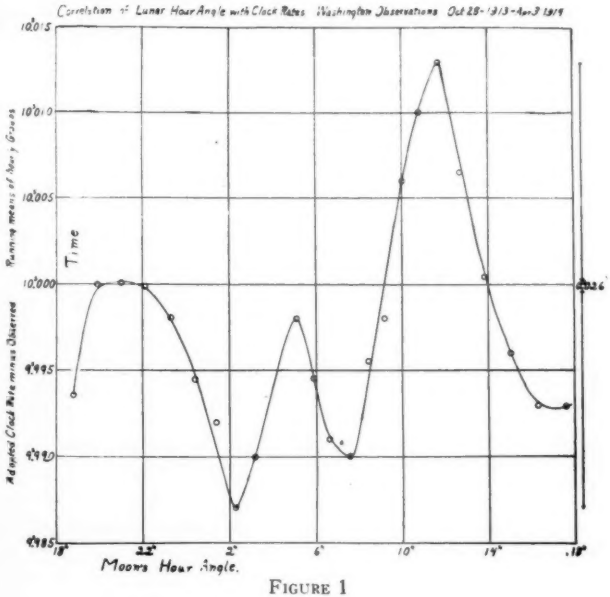

FIGURE 1

stars were used. The positions of the azimuth stars were derived from the Ottawa observations from 1911-1924. The data sent from the Dominion Observatory gave for each day the sidereal time of transit of the first star T_1, the sidereal time of transit of the last star T_2, the sidereal time corresponding to the mean of all time stars T_0, and the observed clock correction at the time T_0. On account of the change in the moon's hour angle it was not thought desirable to include star sets which extended over a period of more than two hours. Using this criterion there were about 4600 observations distributed over 685 nights, and from the given values of T_0 the corresponding hour angles of the moon were calculated. The adopted clock corrections t_a were obtained from the observed clock corrections smoothed twice by taking successive means of

threes.[5] A card catalogue was made up consisting of a card for each night, and each card containing the hour angle of the moon at the time T_0 and the difference between the adopted and observed clock correction at that instant to which ten was added. The cards were divided into twenty-four groups, each group extending over a period of approximately one hour of lunar hour angle, and the mean hour angle and mean residual clock correction were calculated for each group. The points on the curve were obtained from the hourly means by using the running means taking three at a time.

The curves represent the relation between the residual clock correction and the lunar hour angle for Washington and Ottawa. Each point plotted from the Washington data represents on the average 204 ob-

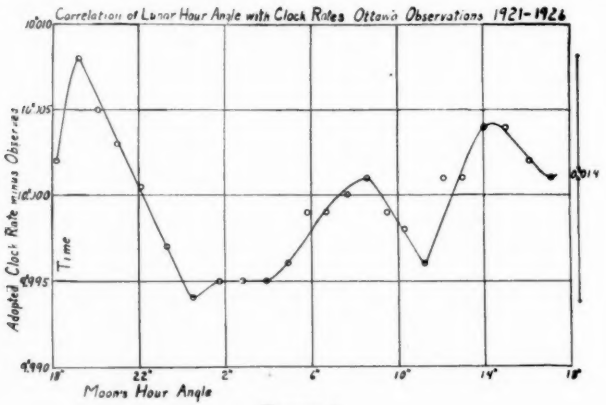

FIGURE 2

servations, and each point plotted from the Ottawa data represents on the average 504 observations. Increasing values of $t_a - t_o$ represent a shifting of the meridian towards the east.

Position of the moon measured from the meridian, when the meridian is moving eastward.		Position of the moon measured from the meridian, when the meridian is moving westward.	
Washington	Ottawa	Washington	Ottawa
6^h E to 3^h E	7^h E to 5^h E	3^h E to 2^h W	5^h E to 1^h W
2^h W to 5^h W	1^h W to 9^h W	5^h W to 8^h W	9^h W to 11^h W
8^h W to 12^h W	11^h W to 14^h W	12^h E to 6^h E	10^h E to 7^h E

The maximum displacement of the meridian at Washington is $0^s.026$ and at Ottawa is $0^s.014$. In discussing the Gaithersburg latitude observations Dr. Stetson obtained $0''.68$ as the maximum displacement of the zenith along the meridian.

The author wishes to express his sincere thanks to Dr. Harlan T.

[5] *Publications of the Dominion Observatory*, Vol. XI.

Stetson of the Perkins Observatory for his many valuable suggestions during this investigation, and to the staff of the Dominion Observatory who so willingly coöperated in sending the results of the Dominion observations.

The Simpler Aspects of Celestial Mechanics

By HOMER A. HARVEY

(Fifth Paper)*

Determination of the Local Time by a Single Altitude

The method involved in this problem, by reason of its application to the determination of longitude at sea, is one of the most important in applied astronomy. The unconscious use of this method is one of our commonest every-day experiences, and everyone is fairly adept at estimating the time of day by the position of the sun. On closer examination it will be seen that even this off-hand process involves the appraisal of the three quantities required by the mathematical solution: (1) the latitude of the observer's station, (2) the day of the year, and (3) the elevation of the sun above the horizon. It will be sufficient to remind the reader that a given elevation of the sun, everything else being equal, will mean a much earlier hour in the morning or a later one in the afternoon in the summer season than in the winter season, in order to convince him that he takes this factor into consideration in his casual estimates. His latitude has naturally long since become a fixed factor in his orientation, and he has learned to allow for the effect of the angle of the celestial equator to his horizon. He will, therefore, not find himself an entire stranger to the more refined solution of the navigator, which we may now investigate.

The problem of the navigator resolves itself into the solution of a spherical triangle whose vertices are marked by the observed celestial body, the zenith, and the celestial pole. This will be made clear by a study of Figure 1.

It will be seen that AB (c) is the complement of the elevation, BC (a) the complement of the latitude, and AC (b) the complement of the declination (with due consideration for the algebraic and geographical conditions of the problem, to be elucidated presently). It follows from these prerequisites that, as has been remarked above, three quantities must be known:

(1) the latitude
(2) the declination

*For preceding papers, see February, April, June-July, and December (1936) issues of Popular Astronomy.

(3) the elevation above the horizon (corrected for refraction, and also for semi-diameter and parallax, in the case of the sun and nearer planets).

The latitude must have been determined prior to the time-sight for longitude, and its value at the moment of observation is estimated at sea from dead reckoning. For the benefit of land-lubbers it may be explained that the navigator makes an accurate determination, at suitable times, of his latitude by observations which indirectly give him the alti-

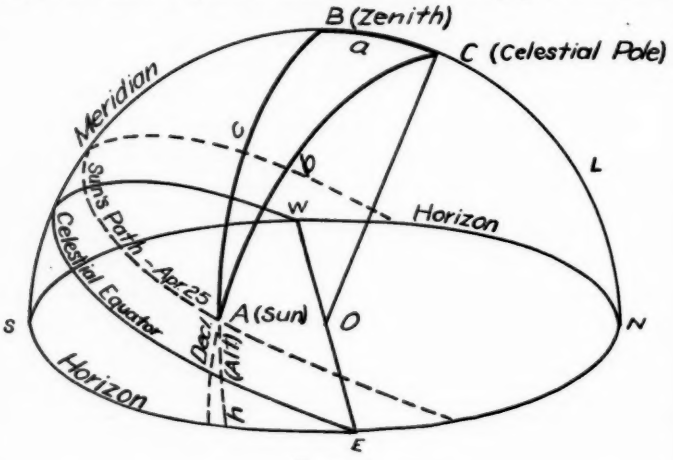

FIGURE 1

The conditions shown are for 65° N latitude, at 8:00 A.M. on April 25. The time triangle ABC is shown in heavy lines. The angle at C is seen to be the Hour Angle of the sun, in this case east of the meridian. a is the complement of the latitude, L; c the complement of the altitude, h; b is in this case the complement of the declination, since the celestial pole shown is assumed to be the North, and the Decl. is the same name (N). It is seen that if the Declination were South, b would be equal to the *sum* of 90° and the declination.

tude of the celestial pole, and hence his latitude, and this quantity is kept corrected up to the time of the next accurate observation by means of the combination of the last reading with the course and the rate of his vessel, together with corrections for wind velocity and current, the whole process being called dead-reckoning. The small error which is thus bound to be present in his estimated latitude may be minimized by making his observation of the celestial object when it is due east or west of the observer, in which case the trigonometrical result of the longitude computations is not seriously vitiated.

Having the three quantities, corrected for the moment of observation, it remains to solve the spherical triangle by the usual formula (three sides given) for the angle BCA, which represents the hour-angle of the observed body east or west of the meridian. In case the sun is observed,

the apparent time can be deduced directly, and the Local Mean Time derived by the application of the Equation of Time. In case a star or planet is observed, angle BCA must be interpreted in terms of local sidereal time, and converted by the usual method into local mean time. In either case, comparison with *Greenwich Mean Time** carried on the ship's chronometer yields the difference between Local Mean Time and Greenwich Mean Time, which is then converted into longitude in accordance with the principles already laid down. Combination of the two coördinates now available, latitude and longitude, gives the navigator his ship's position.

The formula for finding an angle of a spherical triangle, the three sides being given, is

$$\sin C/2 = \sqrt{\sin (s - b) \sin (s - a)/\sin a \sin b}$$

where a and b are the sides opposite the angles A and B, respectively, and s is half the sum of the three sides. For the determination of the polar distance, b, the following rule is applicable:

When declination (+ = N, − = S) and latitude are both N or both S, subtract declination of observed object from 90°; when different, add.

We may now proceed to the solution of an actual problem as it is met on shipboard.

EXAMPLE 1. August 26, 1936, A.M., at sea. Lat. 45° 30′ N. Alt. of sun, (corrected for refraction, parallax, and semi-diameter, (*Bowditch Navigator*), 29° 45′. G.C.T. (chronometer) $10^h\ 20^m$ A.M. What is the local mean time and the longitude?

Decl. sun Aug. 26, 1936, 0^h G.C.T., +10° 33′ 50″ (*Eph.* p. 12)
Daily change, −1253″ (same col.)
Time elapsed since G.C.T. 0^h, $10^h\ 20^m$

Change in declination in that interval = −1253″ × 10.33/24 = −539″ = −8′ 59″
+10° 33′ 50″ − 8′ 59″ = 10° 24′ 51″ Corr. Decl.

Declination and Latitude are both N, hence,

b = 90° − (10° 24′ 51″) = 79° 35′ 9″
a = 90° − 45° 30′ = 44° 30′
c = 90° − 29° 45′ = 60° 15′
s = (a + b + c)/2 = 92° 10′ 5″

$$\sin C/2 = \sqrt{\sin (12° 34′ 56″) \sin (47° 40′ 5″)/\sin (44° 30′) \sin (79° 35′ 9″)}$$

$$= \sqrt{.21783 \times .73926/.70091 \times .98353} = \sqrt{.2335} = .4834$$

whence, C/2 = 28° 54′ 42″ and C = 57° 49′ 24″ = $3^h\ 51^m\ 18^s$
(Hour Angle of sun East of Meridian)
Local Apparent Time = $8^h\ 8^m\ 42^s$ A.M.
Eq. of Time Aug. 26, 1936, 0^h = $-1^m\ 53^s$. Daily change, $+16^s.85$
$+16^s.85 \times (10.33/24) = 7^s.257$
$-1^m\ 53^s + 7^s.3 = -1^m\ 45^s.7$. Eq. of Time at $10^h\ 20^m$ A.M., G.C.T.
$8^h\ 8^m\ 42^s + 1^m\ 45^s.7 = 8^h\ 10^m\ 27^s.7$ L.M.T. at point of observation.

*In the later editions of *The Ephemeris*, this is called Greenwich Civil Time. It is still Mean Time, *i.e.* time kept by a mean or average sun, but the day is counted from midnight, instead of noon, as formerly.

$10^h\ 20^m - 8^h\ 10^m\ 27^s.7 = 2^h\ 9^m\ 32^s.3$. Difference in Time.

This difference in time is equivalent to 32° 24′. Local Time is earlier, hence the point of observation is in longitude 32° 24′ West of Greenwich.

$8^h\ 10^m\ 27^s.7$ L.M.T. 32° 24′ W. Long. Ans.

EXAMPLE 2. On shipboard, Dec. 17, 1936, P.M. Lat., 39° 38′ S., corrected elevation of sun, 22° 18′. G.C.T. of observation $8^h\ 22^m$ P.M. What is the L.M.T. and the longitude?

Decl. sun, Dec. 17, 1936, 0^h G.C.T., −23° 20′ 54″. Daily change, −127″.

$-127'' \times (20.37/24) = -107''.8 = -1'\ 48''$, change since 0^h.

$-23°\ 20'\ 54'' - 1'\ 48'' = -23°\ 22'\ 42''$, corr. decl. sun.

a = 50° 22′ (co-latitude)

Lat. and Decl. are both S, hence b = 66° 37′ 18″ (Polar Dist.)

c = 67° 42′ (co-altitude) s = 92° 20′ 39″

$$\sin C/2 = \sqrt{\sin (25°\ 43'\ 21'') \sin (41°\ 58'\ 39'')/\sin (50°\ 22') \sin (66°\ 37'\ 18'')}$$

$$= \sqrt{(.4341 \times .66884)/(.77014 \times .91791)} = \sqrt{.4108} = .641.$$

Whence, C/2 = 39° 52′; and C = 79° 44′ = $5^h\ 19^m$. H.A. sun W. of Meridian.

L. App. Time = $5^h\ 19^m$ P.M.

Eq. Time Dec. 17, 0^h = $+4^m\ 3^s$ (*Eph.* p. 16)

Daily change = −29^s.5 (same col.)

$-29^s.5 \times (20.37/24) = -25^s$.

$+4^m\ 3^s - 25^s = +3^m\ 38^s$ Corr. Eq. Time for $8^h\ 22^m$ P.M., G.C.T.

$5^h\ 19^m - 3^m\ 38^s = 5^h\ 15^m\ 22^s$ P.M., L.M.T. at point of observation

$8^h\ 22^m - 5^h\ 15^m\ 22^s = 3^h\ 6^m\ 38^s$.

This difference in time is equivalent to 46° 39′ 30″ of longitude. Since the local time is earlier than that of Greenwich, the local station is West of Greenwich.

$5^h\ 15^m\ 22^s$ L.M.T. 46° 39′ 30″ W. Longitude. Answer.

If we examine the formula for the solution of the time-angle we find some interesting facts arising from special cases. If we read an altitude of the sun at apparent noon, i.e., when the sun is on the meridian, and construct the resultant triangle, we will find that the polar distance, b, falls upon a and c and equals their sum. s therefore becomes equal to $2b/2 = b$. The first factor under the radical becomes zero. Hence the time-angle C will equal zero. The spherical triangle has become a straight line upon the meridian.

Similarly, if we imagine the observation to be made at the pole, a always equals zero. The triangle has disappeared, not only for apparent noon, but for all times of day, and is hence insolvable. We may conclude, therefore, that determining the time at the pole by astronomical methods is impossible.

This method is of course not limited to the sun, but may be used in connection with any celestial object whose identity and ephemeris are known.

EXAMPLE 3. At sea, April 23, 1936, P.M. Lat. 3° 20′ N. Corrected altitude of Aldebaran, west of meridian, 25° 32′. G.C.T. by chronometer, $6^h\ 54^m$ P.M. What was the L.M.T. and the longitude?

Aldebaran, R.A. $4^h\ 32^m\ 16^s$, Decl. +16° 22′ 58″.

Our problem here concerns itself with sidereal time intervals. Hence we may begin by finding the Greenwich Sidereal Time of the observation. This is the sum of two components, both of which are available (1) the hour-angle of the Mean Sun, and (2) the R.A. of the Mean Sun, reduced to the hour of the observation. This method of finding Sidereal Time will be an advantage to the student, as being a graphic one, and readily seen in a figure.

		h m s
(1)	H. A. mean sun	6 54 0
(2)	R. A. mean sun 0^h	2 3 26
	Gain in R.A. in $18^h\ 54^m$, [$3^m.97 \times (18.9/24)$]	+ 3 8
	G. S. T. (R. A. Vern. Eq.)	9 0 34
	R. A. Aldebaran	4 32 16
	H. A. Aldebaran at Greenwich	4 28 18

Solving the spherical triangle involving Aldebaran:

$a = 86° 40'$ co-latitude ($90° -$ latitude)

Decl. and Lat. both N, $b = 73° 37' 2''$ polar dist. ($90° -$ decl. Aldebaran)

$c = 64° 28'$ co-altitude ($90° -$ altitude Aldebaran) $\quad s = 112° 22' 31''$

$$\sin C/2 = \sqrt{\sin (38° 45' 29'') \sin (25° 42' 31'')/\sin (86° 40') \sin (73° 37' 2'')}$$

$$= \sqrt{(.62603 \times .43378)/(.99831 \times .95940)} = \sqrt{.2836} = .5325$$

Therefore, $C/2 = 32° 10'$, and $C = 64° 20'$, which is equivalent to $4^h\ 17^m\ 20^s$ of time.

This is the H. A. of Aldebaran at the local station.

H. A. Aldebaran at Greenwich	$4^h\ 28^m\ 18^s$
H. A. Aldebaran at local station	4 17 20
Difference in time	10 58

which is equivalent to $2° 46'$ of longitude.

Local Time is earlier than Greenwich Time—hence W. Longitude.

G.C.T. $6^h\ 54^m$ P.M. $- 10^m\ 58^s = 6^h\ 43^m\ 02^s$

$6^h\ 43^m\ 02^s$ L.M.T. $\quad 2° 46'$ W. Longitude. $\quad$ Answer.

If a planet is used for the observation, the process is the same as for a star, except, that since the planet is a movable object, correction must be made for the R.A. and Decl. of the planet in accordance with the G.C.T. of the observation.

EXAMPLE 4. At sea, July 26, 1936, P.M. Lat. $25° 12'$ S. Observed corrected altitude of Jupiter, west of the meridian, $32° 16'$. G.C.T. by chronometer, $2^h\ 12^m$ A.M. What was the L.M.T. and the longitude?

July 26, 1936, 0^h G.C.T. (*Ephemeris*, p. 187)—

R. A. Jupiter $\quad 16^h\ 55^m\ 8^s$

Decl. Jupiter $\quad -22° 10' 23''$

Daily change in R.A. $= -12^s.7$; in Decl. $= +8''.3$.

Change in R.A. and Decl. in $2^h\ 12^m$—

$-12^s.7 \times (2.2/24) = -1^s.17$

$+8''.3 \times (2.2/24) = +0''.76$

Corrected R.A. and Decl. for $2^h\ 12^m$ A.M.—

$16^h\ 55^m\ 8^s - 1^s.17 = 16^h\ 55^m\ 6^s.8$

$-22° 10' 23'' + 0''.76 = -22° 10' 22''.2$

To find H.A. of Vernal Equinox (Sid. Time) at Greenwich—

		h	m	s
(1)	H.A. mean sun at Greenwich	14	12	0
(2)	R.A. mean sun 0^h, July 26, 1936 (*Eph.* p. 10)	8	14	2
	Increase in R.A. in $2^h\ 12^m$ [$3^m.95 \times (2.2/24)$]			21.8
	G.S.T.	22	26	23.8
	R.A. Jupiter at $2^h\ 12^m$ A.M.	16	55	6.8
	H.A. Jupiter at Greenwich	5	31	17

Solving the spherical triangle involving Jupiter:

$a = 64° 48'$ co-latitude $(90° - \text{latitude})$

Altitude and latitude same sign, $b = 67° 49' 37''.8$ polar dist. $(90° - \text{decl.})$

$c = 57° 44'$ co-altitude $(90° - \text{altitude})$. $s = 95° 10' 49''$

$$\sin C/2 = \sqrt{\sin (27° 21' 11'') \sin (30° 22' 49'')/\sin (64° 48') \sin (67° 49' 38'')}$$

$$= \sqrt{(.45947 \times .50565)/(.90483 \times .92605)} = \sqrt{.2773} = .5265$$

Therefore, $C/2 = 31° 46'$, and $C = 63° 32'$

which is equivalent to $4^h\ 14^m\ 8^s$ of time.

This is the H.A. of Jupiter at the local station.

H.A. Jupiter at Greenwich	$5^h\ 31^m\ 17^s$
H.A. Jupiter at local station	4 14 8
Difference in Time	$1^h\ 17^m\ 9^s$

which is equivalent to $19° 17' 15''$ of longitude.

Local time is earlier, hence W. longitude.

G.C.T. $2^h\ 12^m$ A.M. $- 1^h\ 17^m\ 9^s = 0^h\ 54^m\ 51^s$ L.M.T.

$12^h\ 54^m\ 51^s$ A.M., L.M.T. $19° 17' 15''$ W .Longitude. Answer.

It is recommended that the student make a drawing to illustrate the conditions of the last two problems. The quantities will then be readily seen and their derivation become a simple matter. The sun's path for the given day should be drawn in, and the positions of the vernal equinox and the given celestial object shown upon this line by projection. The sun's position for the given time of day is then shown, and with these three positions laid down along the same celestial circle the numerical equivalents will become readily ascertainable.

By trigonometrical transformation the usual formula for the solution of the spherical triangle may be altered so that the h and L (altitude and latitude) may be used directly, thus eliminating the subtraction processes. In this form the formula reads

$$\sin C/2 = \sqrt{\sec L \operatorname{cosec} p \cos s \sin (s - h)}$$

where $s = (h + L + p)/2$.

(p = polar distance; L = latitude; h = elevation.)

Certain corrections in the actual practice of taking time sights with a sextant have not been mentioned, since they belong primarily to the instrument and the circumstances rather than to the problem itself. Such are the correction for the index-error, or amount of adjustment error in the sextant, and the correction for the height of the eye above the level

of the water (see first paper). All the necessary corrections to be applied to the altitude reading are to be found in tabulated form in the *Bowditch Navigator,* and their application is a simple matter. The amateur may be assured that the first requisite for the would-be navigator is a grasp of the foregoing principles, and that the practical manipulations follow naturally as a matter of experience. With the advent of transoceanic airways the day may presently come when navigation may be a commoner knowledge than was ever dreamed of by our land-bound forebears.

BATAVIA, NEW YORK.

Planet Notes for April, 1937

Note: All times, unless otherwise stated, are Central Standard Time.

The *Sun* during this month will move in a northeasterly direction, passing from the constellation Pisces into the constellation Aries. It will be in a region of the sky in which there are no conspicuously bright stars. The earth will continue to recede from the sun, passing through the mean distance on April 2.

The phenomena of the *Moon* will occur as follows:

Last Quarter	April	3	at 10	P.M.
New Moon		11	" 11	P.M.
First Quarter		17	" 3	P.M.
Full Moon		25	" 9	A.M.
Perigee		12	" 2	A.M.
Apogee		27	" 4	A.M.

Mercury at the beginning of the month will be a short distance east of the sun, and will be moving eastward more rapidly than the sun. This motion will bring it to a point of greatest elongation east on April 19, when it will be somewhat more than an hour east of the sun. It will be slightly south of the sun, which fact will hasten its setting. However, near this date a persistant searcher may secure a glimpse of this planet especially if he has setting circles on his instrument to guide him and a favorable horizon. Before the end of the month the sun will be overtaking the planet rapidly. Its stellar magnitude will be about 0.0.

Venus will still be a brilliant object in the sky at the beginning of this period. Its motion will be westward which, combined with the eastward motion of the sun, will bring these two objects into conjunction on April 17. This is an inferior conjunction, which means that Venus will be on the earthward side of the sun. At this time the planet will be about six degrees north of the sun. Its stellar magnitude will be practically —3.5.

Mars will be well situated for observation during this period, as it will rise soon after sunset. About the middle of the month it will change from an apparent eastward motion to an apparent westward or retrograde one. After that time for the remainder of the month it will rise four or five minutes earlier from night to night. It will, however, be rather far south for northern observers, being twenty degrees south of the equator. Mars will be rather close to the earth, relatively speaking, during this time, and consequently it will be relatively bright, of magnitude about 0.7.

Jupiter will rise about midnight and will be observable in the early morning hours. It will be at quadrature, west of the sun, on April 16. This planet, like Mars, will be quite far south, its declination being 21° south. Jupiter will be moving nearer to the earth during this interval, the light-time diminishing from 43.95 minutes on April 4 to 41.17 minutes on April 25.

Saturn will be only a short distance west of the sun and slightly south of it. Consequently it will rise just before sunrise and will not be favorably situated for observations.

Uranus will gradually be lost in the rays of the sun. On the first day of the month it will be somewhat less than two hours east of the sun and on the last day it will be in conjunction with the sun. It will be a short distance south and west of the Pleiades. On April 1 it will be found in R.A. $2^h\,23^m$ and Decl. $+13°\,46'$.

Neptune will be in the constellation Leo, a short distance southeast of Regulus. It will be visible practically throughout the night. On April 15 it will be found in R.A. $11^h\,13^m$ and Decl. $+6°\,17'$.

Asteroid Notes

By HUGH S. RICE

Residuals

Residuals in planet observing are the algebraic differences between the actually observed and the previously computed positions. In looking over the residuals of the asteroid ephemerides that appear in these notes within the last year, we find that some of our choices have not been very good. Unfortunately it is not easy to determine before publication of this magazine the accuracy of such ephemerides, except those of Vesta. In the case of this planet there are special tables (Leveau's tables) by which calculation of the planet's places is rendered so exact as to be comparable with the positions of the major planets. The following table gives residuals of the objects in the ephemerides published. They are based on professional observations made in the leading observatories of the world specializing in this work. Residuals are marked "O — C", meaning observed minus computed values.

Planet	O — C α	O — C δ	Planet	O — C α	O — C δ
5 Astraea	$+1^m3$	+ 1′	354 Eleonora	-0^m4	+ 2′
18 Melpomene	—14.9	—70	387 Aquitania	0.0	+13
20 Massalia	— 2.5	+10	532 Herculina	— 6.8	+18
40 Harmonia	— 0.9	0	737 Arequipa	+ 1.2	+ 4
97 Klotho	— 5.5	—20	192 Nausikaa	+ 0.8	— 3

Naturally, the larger the residual, the harder the planet is to find. In all cases a wide field-of-view should be used in the telescope, to include as large a section of the sky as possible at one time. Even with a large field it is very difficult to locate an asteroid that is as far from its computed place as was Melpomene (14^m9 or about $3\frac{3}{4}$ degrees). These residuals are caused by the perturbing action of the major planets, particularly Jupiter, making the asteroid deviate from its computed place. In the case of Melpomene, Dr. Kahrstedt of the Astronomisches Rechen-Institut computed, by means of Schubert's tables, four positions corresponding to four observations made by Meyer at Rutherford, and the residuals were reduced to about 2′! In other words, by the use of new actual observations

another ephemeris was computed, that fitted the actual places as observed, to a value much nearer than the old one. Planet 387 Aquitania proved a difficult object to observe because it was a whole magnitude fainter than predicted.

Not all of the results are like this. Among the many asteroids whose ephemerides are published and which are observed photographically or otherwise, there are very many in the course of a few months, that have very small residuals. As observed since December 1, the following are among the planets whose residuals have been found to be "zero-zero" or 0^m0 in R.A. and 0′ in Decl.: 4 Vesta, 11 Parthenope, 250 Bettina, 209 Dido, 17 Thetis, 175 Andromache, 803 Picka, 21 Lutetia, 10 Hygiea, 27 Euterpe, 1936 WA, 893 Leopoldina, and 3 Juno. These were reported from the Rechen-Institut bulletins, and were all seen at foreign observatories, except 3, 10, and 27 which were observed at Rutherford by Meyer. Besides these, many others had residuals departing but slightly from the above. The Astronomisches Rechen-Institut is to be highly complimented on doing such exhaustive work on minor planets, for with the many hundreds of them known it is a prodigious undertaking.

The Big Four

This term, the Big Four, was first suggested to the writer by Sanders, of Baltimore, to include Ceres, Pallas, Juno, and Vesta. It may be remarked that the user of the small telescope need not find the locating of these miniature worlds difficult, if our directions are followed. Mr. Sanders made 80 observations of Iris between August 20 and January 16, as well as 25 of Melpomene at the latter's last apparition. He has made in all, 675 observations of minor planets, all due to the "inspiration" of these columns! Also, 25 more were made on Eros.

Vesta is still observable at this time, in Gemini. On March 15 it is about 3° north of μ Geminorum; on April 7 it passes 19′ north of ϵ Geminorum, and is about 3° east of that star on April 15, continuing its eastward motion. The magnitude on April 1 is 7.8. Juno is much fainter on this date—9.4. On March 15 it is about 4° northwest of γ Virginis, and it proceeds to a position about 2° southwest of π Virginis at the end of April; its motion therefore is retrograde, as the opposition takes place March 25. Rising before the sun are two more of the Big Four. Pallas on March 15 is about $2\frac{1}{2}$ degrees south of ω Aquilae; it then pursues a northeast course and is about $2\frac{1}{2}$ degrees southeast of β Sagittae at the end of April. Magnitude averages 9.7. The other one is Ceres, but this is still too near the sun to observe conveniently. As its opposition occurs in August, it will be a summer object, but will then be placed in Piscis Austrinus, quite low for northern observers.

Fainter Planets; Variation in Delta

We give the ephemerides of planets coming to opposition shortly, and they are the best, as to brightness and location, for observation with moderate-sized telescopes. The variation ("var.") is the algebraic difference in declination, corresponding to a residual of $+1^m$ in right ascension. For instance we wish to observe 8 Flora on March 16. Now we do not know that Flora's ephemeris is exact, so that after plotting the given positions on a star chart we make use of the variation in δ, to determine two additional possible places, thus:

α	δ	
$13^h\ 25^m0$	$+1°\ 4'$	[$+4.0 \times (-6'.0) = -24'$, added to 1° 28′]
13 21.0	+1 28	[ephemeris position]
13 17.0	+1 52	[$-4.0 \times (-6'.0) = +24'$, added to 1° 28′]

These three positions determine a line close to which the planet will be found, as-

suming the residual (amount by which the ephemeris *may* depart from the actual position) to be no greater than 4^m in α. In determining the two auxiliary places, we could easily have used any variation in α; the 4.0 was taken for convenience. In the ephemeris, Δ is the log of the distance from the earth in astronomical units. The number corresponding to it is to be multiplied by 92,897,416 miles, to get the actual distance. It is now our practice to cover the last half of the month of the issue of the magazine, and the following month.

EPHEMERIDES OF ASTEROIDS FOR 0^h U.T. EQUINOX 1925.0

113 AMALTHEA $10^M.5$

		α h m	δ ° ′
Mar.	8	12 57.3	+1 59
	16	12 52.3	+2 59
	24	12 46.1	+4 0
Apr.	1	12 39.3	+4 58
	9	12 32.4	+5 48
	17	12 26.2	+6 26

Var., −5′.8 $\Delta = 0.073$

8 FLORA $9^M.7$

		α h m	δ ° ′
Mar.	16	13 21.0	+1 28
	24	13 14.4	+2 25
Apr.	1	13 6.8	+3 21
	9	12 59.0	+4 13
	17	12 51.3	+4 55
	25	12 44.4	+5 25

Var., −6′.0 $\Delta = 0.184$

6 HEBE $9^M.6$

		α h m	δ ° ′
Apr.	1	13 57.6	+ 8 39
	9	13 51.3	+ 9 46
	17	13 44.4	+10 43
	25	13 37.5	+11 28
May	3	13 31.0	+11 59
	11	13 25.3	+12 15

Var., −4′.0 $\Delta = 0.290$

660 CRESCENTIA $10^M.2$

		α h m	δ ° ′
Apr.	1	14 4.2	+ 6 18
	9	13 59.0	+ 7 52
	17	13 52.9	+ 9 16
	25	13 46.7	+10 26
May	3	13 40.8	+11 19
	11	13 35.7	+11 51

Var., −2′.8 $\Delta = 0.150$

Hayden Planetarium, American Museum of Natural History,
New York City, February 23, 1937.

OCCULTATION PREDICTIONS

(Taken from the *American Ephemeris*)

OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′.

Date 1937	Star	Mag.	IMMERSION Greenwich C.T. h m	IMMERSION *a* m	IMMERSION *b* m	IMMERSION Angle E from N °	EMERSION Greenwich C.T. h m	EMERSION *a* m	EMERSION *b* m	EMERSION Angle E from N °
Apr. 15	108 Tau	6.2	3 14.1	0.0	−0.5	59	3 53.2	+0.7	−1.7	314
22	*e* Leo	5.1	5 10.9	−1.7	−0.7	71	6 2.1	−0.5	−2.9	344
30	21 G.Sgr	5.7	4 35.4	−1.6	+2.7	48	5 32.2	−0.9	−1.0	315

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′.

Apr. 15	108 Tau	6.2	3 13.9	−0.2	−1.0	86	4 6.5	+0.3	−1.4	289
22	*e* Leo	5.1	4 35.6	−2.0	−0.9	103	5 54.1	−1.1	−2.3	321
28	*p* Oph	4.8	9 32.3	..	..	164	9 59.0	..	..	199

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′.

Apr. 15	108 Tau	6.2	3 8.8	−0.5	−2.4	132	4 3.0	−1.1	−0.3	245
15	*n* Tau	5.1	4 56.0	+0.4	−2.6	145	5 34.2	−0.6	0.0	232
21	237 B.Leo	6.3	9 44.7	−0.7	−0.4	62	10 23.2	0.0	−3.0	347
22	*e* Leo	5.1	3 56.1	−0.7	−2.4	164	5 4.0	−2.8	+0.4	266

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result, in degrees, taking the

signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Gamma Cassiopeiae: There has been considerable interest in recent months in the question of the variability of the well-known star, Gamma Cassiopeiae. This interest began with the announcement of E. H. Cherrington, of the Perkins Observatory, that the star was abnormally bright, magnitude 1.6, on October 5, 1936. This seemed unusual, in view of the fact that the standard accepted magnitude had been considered as 2.25, on the Harvard Revised Photometry scale, only slightly fainter than Polaris.

Visual observations were immediately undertaken and estimates of brightness varying between 1.6 and 2.2 were being reported from different stations and within short intervals of time.

In the August number of *L'Astronomie*, P. Blaize reports an increase of light for the star, as of July 25, 1936, magnitude 1.85, based on observations with several comparison stars. No appreciable change from this value was noted by him over an interval of eleven days. Between October 19, 1936, and January 4, 1937, W. A. Calder, using the photoelectric cell at Harvard, observed this star on nineteen nights, employing Beta and Epsilon Cassiopeiae as comparison stars, and found little, if any, variation; certainly not exceeding two hundredths of a magnitude. These observations will be published soon in a Harvard Bulletin.

Accordingly, it would appear that since October, 1936, the major part of the reported fluctuations in the light of Gamma Cassiopeiae, is due, mainly, to changes in atmospheric absorption, when the star is at a widely different altitude with respect to the comparison star used. By this, it is not to be implied that Gamma Cassiopeiae was not faint in earlier years. An examination of the early Harvard photometric catalogues shows that the observed magnitudes there cited agree within a tenth of a magnitude and give a mean value of 2.25. Various earlier visual catalogues also give a similar result. We may therefore conclude that at the times when observations were made for these catalogues the star was constant and at about magnitude 2.25.

W. H. Smyth, in his 1844 edition of the "Cycle of Celestial Objects," calls attention to the suspected variation of Gamma Cassiopeiae by John Herschel, as far back as 1838. Smyth states that he regrets that more attention had not been paid to Gamma Cassiopeiae, as a possible variable, rather than to Alpha Cassiopeiae. Alpha Cassiopeiae has been suspected of variation for a long time and is listed in the latest catalogue with a range of half a magnitude (2.1 to 2.6), spectral class G8. No regular period has ever been obtained for this star and estimates of magnitude are subject to a large uncertainty, when observed by different individuals.

Gamma Cassiopeiae is a well-known double star with an eleventh magnitude

companion of 2".2 distant, and a second companion distant 52".7. The nearer companion appears to be moving with the principal star and they probably constitute a physical system. The more distant companion is increasing its distance with respect to the main star, Gamma.

Spectral changes in Gamma Cassiopeiae have been noted for a number of years. Secchi and Huggins, in 1868, described bright hydrogen lines as appearing but no mention is made of D3, although it was seen by both of these observers in other years. In 1872, Vogel suspected the presence of D3 as well as faint dark bands in the red. He made no mention of the C line. Other observers, such as

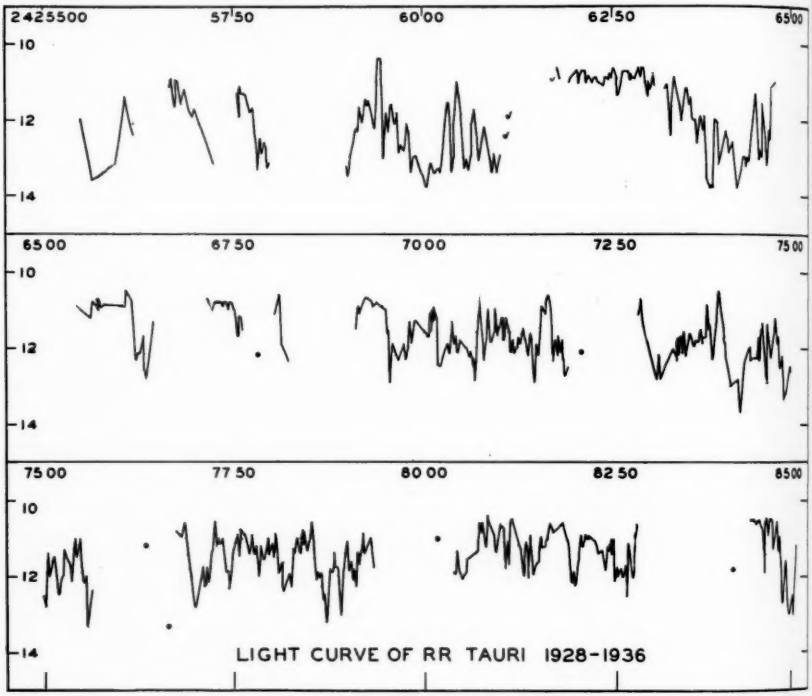

FIGURE 1

Konkoly, Gothard, Maunder, Keeler, and Bélopolski, between the years 1874 and 1892, report D3 as visible at times, while on other occasions it was invisible. Scheiner did not believe it possible that dark lines could exist in the spectrum of Gamma Cassiopeiae, since none had been seen on the Potsdam plates.

The classification of the star by Miss Cannon gives the spectral type as Bope: having bright and dark lines. In a paper presented at the recent meeting of the American Astronomical Society, Dr. Cherrington notes that the D lines in emission increased in intensity from October 6 to December 18. On December 24, these lines disappeared entirely, while on December 25, D2 reappeared in absorption. HeI line 6678 has changed from weak absorption in 1933, to strong emission at the

present time. J. F. Heard, of the University of Toronto, has made some spectrograms of Gamma Cassiopeiae which continue to show marked changes in the spectrum of the character observed in 1934, but at this time apparently more noticeable.

It has been hinted in some publications that this change in the brightness of Gamma Cassiopeiae was in the nature of an outburst and this has been interpreted by some as possibly indicating that the star is in a stage where it might, at some future time, take on the characteristics of a nova. With the data at hand, there would seem to be little foundation for this interpretation. While observations of this star should doubtless be maintained for some time to come in order to note any radical changes in brightness, it is quite evident that more reliable and valuable observations can be gained by the photoelectric method, as illustrated by the work of Dr. W. A. Calder.

The Variable RR Tauri: The irregular variable star RR Tauri, 053326, was discovered by Mme. Ceraski in 1900. Since 1928, this star has been under observation by A.A.V.S.O. observers rather continuously up to the present time. Although annual light curves (from 1932-1935, inclusive) have appeared in *Harvard Circulars,* it is desirable to present the material for 1928 to 1936 in graphical form herein (Fig. 1) in order that observers may have a more comprehensive idea as to how the star has behaved during these years. During this time, the extreme range has been from 10.4 to 13.8 and it will be noted that there seems to be no evidence of regularity in light changes. Sometimes these light variations occur within an interval of ten days or less. From time to time various possible periods have been assigned, from two days to two hundred and ten days, but later observations do not confirm any of these values. The star is one which should be closely observed by all variable star observers.

SS Cygni Type Variables: SS Cygni itself has continued to act in a peculiar manner since the decrease to minimum from maximum No. 279. Maximum No. 280 proved to be of the anomalous type, hardly attaining the magnitude 9.8. There was another marked rise, about January 15, and toward the end of the month the variable was well on towards a bright maximum, but with slow rise. SS Aurigae was at maximum on January 24.

Observers and Observations: New observers listed among the contributors to the A.A.V.S.O. reports received during January include: Richard Evans, of Milwaukee, Wisconsin; Neil McNabb, Jr., of Acton, Ontario, Canada; and Albert E. Scherr, of Scarsdale, New York. Seventy observers contributed 4393 observations during this month and they are listed below, together with the number of variables and observations which each made.

Name	Vars.	Observations	Name	Vars.	Observations
Ahnert	38	311	Chartier	19	32
Ancarani	9	13	Diedrich	1	5
Atchison	1	2	Ellis	3	3
Baldwin	41	50	Ensor	54	106
Ballhaussen, Miss	27	31	Escalante	77	106
Blunck	42	62	Evans	1	12
Bouton	69	114	Fairbanks	6	8
Brocchi	9	9	Franklin	11	20
Brown, S. C.	10	10	Gregory	32	32
Buckstaff	6	7	Hartmann	148	323
Callum	20	30	Herbig	62	124
Carpenter	54	77	Hiett	12	26
Chandra	257	631	Hildom, A.	30	51

Name	Vars.	tions Observa-	Name	Vars.	tions Observa-
Holt	43	79	Plakidis	1	16
Houghton	57	128	Purdy	7	7
Houston	40	94	Recinsky	7	12
Howarth	9	14	Rosebrugh	27	86
Humbert	4	4	de Roy	10	42
Jones	110	377	Ryder	8	14
King	5	5	Scanlon	9	9
Kirkpatrick	22	95	Schattle	4	32
Kitchens	25	26	Scherr	2	2
de Kock	37	130	Schmidt, R.	2	5
Kohman	21	26	Shinkfield	17	22
Koons	9	10	Sill	22	22
Kotsakis	13	94	Smith, F. P.	22	26
Kozawa	9	122	Smith, F. W.	1	3
La Fon	19	27	Smith, L.	4	4
Loreta	124	239	Strelitzer	9	9
MacCalla	6	9	Thorndike	8	8
McLeod	17	38	Thorne	6	7
McNabb	1	2	Treadwell	11	28
Millard	13	21	Vassar College	12	12
Murphy	18	35	Webb	20	27
Peck	17	77			
Peltier	156	171	70		4393

Times of Minima for Bright Eclipsing Variables: Herewith is given a table of times of minima, expressed in Eastern Standard Time, once in each month, March to June inclusive, for eight eclipsing variable stars. Other times of minima may be easily deduced by adding to the time expressed in the table the period given in the last column.

The drop to minimum for eclipsing stars usually begins several hours before the time stated and a corresponding interval of time is required after minimum for the variables to resume their former maximum brightness. The times are expressed in Civil Time, a for A.M., and p for P.M. One hour should be subtracted for Central Standard Time, two hours for Mountain Time, and three hours for Pacific Time. The data used in this table have been extracted from the very convenient Ephemerides of Eclipsing Stars, compiled by Professor T. Banachiewicz and published under the auspices of the International Astronomical Union.

EPHEMERIS FOR BRIGHT ECLIPSING VARIABLES

(Eastern Standard Times of Minima)

Variable	March	April	May	June	Period
	d h m	d h m	d h m	d h m	d h m
U Cephei	2 3:38p	2 1:43p	2 11:34a	1 9:38a	2 11 50
β Persei	2 1:29p	3 2:26a	1 6:49p	2 7:43a	2 20 49
λ Tauri	1 6:46p	2 9:53a	. . .	16 12:17p	3 22 52
δ Librae	3 1:14p	2 7:29p	3 1:29a	2 7:43a	2 7 51
U Cor. Borealis	3 5:34a	3 7:14a	4 8:55a	4 10:36a	3 10 51
U Ophiuchi	2 10:22p	2 3:10a	2 7:43a	1 12:17p	1 16 15
β Lyrae	4 12:02a	11 7:00p	7 3:38p	2 12:02p	12 22 16
Z Vulpeculae	3 6:17a	1 5:19p	3 3:10p	2 2:12a	2 10 55

Note on the Coming Eclipse of Zeta Aurigae

On April 22, 1937, the B component of ζ Aurigae will again enter eclipse. This year the star, unfortunately, will be rather far west before observing can be commenced in the evening. Every effort, however, should be made to determine the brightness of the star for at least a week preceding totality.

It is to be hoped all who have suitable equipment will coöperate in observing this interesting star. Fourteen observatories in Europe and Asia have already signified their willingness to undertake observations and we trust that many competent amateurs will also join in the effort to obtain a satisfactory light-curve. The writer will be glad to receive any observations as soon as possible after the eclipse, and to reduce the measures, and transfer them into a homogeneous system, for those who do not care to undertake this work themselves.

WILLIAM H. CHRISTIE.

Carnegie Institution of Washington, Mount Wilson Observatory,
Pasadena, California, February 2, 1937.

The Luminosities of Variable Stars of Class M with Non-emission Spectra

The purpose of this paper is to discuss the material bearing on the luminosities of variable stars of spectral class M, other than the Me stars. The non-emission variables of class M are common and some of them are bright, even conspicuous, stars, yet so far as the writer knows, about all that has been done with the problem of their luminosities has been to measure the parallaxes of a few of the brighter members of the group. That is the reason for this paper.

The aspect of the luminosity problem that will first be touched upon is the luminosity of stars in systems of known distance. Hubble has found variable stars of spectral class M in the Great Nebula of Andromeda. These stars have absolute magnitudes as bright as —4. According to Shapley, the mean absolute magnitude of the Class M irregular variables in the Large Magellanic Cloud is —3.3. (See "The Stars of High Luminosity," by Miss Cecilia Payne, pages 44 and 58.)

The indications of most of the trigonometric parallaxes, so far published, point towards high luminosity for the non-emission class M variables. Parallaxes for ten of these stars are published in Schlesinger's "Catalog of Bright Stars." The individual luminosities from these parallaxes range from absolute magnitude —3.0 for Betelguese to —0.35 for ρ Persei. Five of the stars are brighter than absolute magnitude —2.0 at maximum light. If the mean absolute magnitude formula given in equation (1) of *Mount Wilson Contributions,* No. 267, be applied to the parallaxes, the mean absolute magnitude at maximum light for all ten stars is —2.05.

The proper motions and radial velocities of the non-emission variable stars of class M yielded the results given below. The proper motion stars, 22 in number, were taken from Schlesinger's "Catalog of Bright Stars" and the "Harvard Catalog of Long-Period Variables," by Townley, Cannon, and Campbell. The radial velocity stars, 14 in number, were taken from Schlesinger's "Catalog of Bright Stars," and from *Mount Wilson Contributions,* No. 264, by Paul W. Merrill.

The position of the solar apex chosen is at 18^h, $+30°$. The value obtained for the solar motion was 32.6 km/sec and the value for the mean peculiar radial velocity obtained was 14.4 km/sec. (For the formulae used see W. W. Campbell, "Stellar Motions," Chapters V and VI.)

The proper motions were resolved into their upsilon and tau components, then these components were reduced to the basis of apparent magnitude 5.0 at maximum light. (For the formulae for these operations, see Merrill and Stromberg, *Mount Wilson Contributions,* No. 267.) The solution for the mean parallaxes was made according to the formulae on pages 663 and 664 of Russell, Dugan, and Stewart's "Astronomy." The mean parallax from the upsilon components is $0''.0036$; that from the tau components is $0''.0094$. Investigation of the details of

the computation shows that the mean parallax from the upsilon components is entitled to two-fifths the weight of that from the tau components. The final adopted mean parallax from proper motions and radial velocities is 0".0077, which at apparent magnitude 5.0, to which basis the proper motions were reduced, corresponds to a mean absolute magnitude at maximum light of —0.57. A result differing so markedly from previous results requires explanation. The explanation lies in the fact that the list of proper motion stars contains a large percentage of stars with extremely late spectra such as R Doradus and W Persei. These stars, which have much larger reduced proper motions than the other non-emission variable stars of class M, are, owing to large heat index and very strong band absorption, fainter to a rather marked degree than such stars as Betelguese and μ Cephei. These stars, with absolute magnitudes of about 0 at maximum, cannot be seen in distant systems and are at present absent from our lists of parallaxes.

As far as the scanty but rather varied data on the subject would indicate, the variable stars with non-emission spectra of class M are divided into three groups with regards to luminosity.

(a) A group of bright super-giants around absolute magnitude —3.3. These stars are for the most part irregular variables and, though few in number, are fairly conspicuous in our catalogs.

(b) A group of ordinary super-giants around absolute magnitude —1.5, including such stars as β Pegasi and η Geminorum. Many of these stars are long-period variables, though irregular stars are known in this group. The chief reason for separating groups (a) and (b) is the data from the Large Magellanic Cloud. Further data may merge these two groups. They are certainly more closely related to each other than either is to group (c).

(c) The typical stars are R Doradus and W Persei. The absolute magnitude, though not well determined, is around 0. The spectrum is generally of subclass Mc. The stars are for the most part long-period variables. The range of variation is greater, and the radial velocities seem, from the scanty data at present available, to be higher than for groups (a) and (b). The group shows close relations with the Me long-period stars.

NOAH W. MCLEOD.

Christine, North Dakota.

Comet Notes

By G. VAN BIESBROECK

Two faint comets have been announced during the last month.

PERIODIC COMET DANIEL (1937 *a*). This is a return of the comet that was discovered by Z. Daniel at Princeton, New Jersey, on 1909 December 6: It appeared then as a round coma with a well-defined nucleus, the total magnitude corresponding to that of a 10^M star. A short, very faint tail-like extension was noticed by some observers. Computations showed that the orbit was elliptical and that perihelion time had occurred a week before discovery. The brightness gradually diminished but the comet was followed until 1910 April 11 when it was last photographed by M. Wolf at Heidelberg.

The orbit was carefully investigated by A. D. Doubiago who found the period to be 6.48 years. Taking into account large perturbations by Jupiter in 1911 and 1912 he gave an ephemeris for the return in 1916 but the object was expected to be faint and a photographic search both at Heidelberg and Bergedorf failed to reveal

the presence of the comet. Later returns in 1923 and 1930 remained unobserved. This winter Mr. H. Hirose of Tokyo (Japan) resumed the computations for the fourth return since the discovery; he had noticed that the conditions of visibility were favorable at this return. With the help of this prediction Mr. Simizu luckily located the object near the expected position. On January 31 it appeared as a 13M diffuse object without nucleus. Cloudy weather has prevented observations at Williams Bay, but at Oakridge and Harvard the comet was recorded on February 12 as a diffuse coma some 15″ in diameter and of magnitude 15.

The elements for this return, computed by Hirose are:

$$\left.\begin{aligned} T &= 1937\ \text{Jan.}\ 27.940\ \text{U.T.} \\ \omega &= 6^\circ\ 1' \\ \Omega &= 70\ 19 \\ i &= 19\ 50 \end{aligned}\right\} 1937.0$$

$$e = 0.5729$$

$$\text{Period} = 6.83\ \text{years}$$

giving the ephemeris:

1937		α h m	δ ° ′
Feb.	28	3 26.4	+28 12
Mar.	4	37.7	29 34
	8	49.3	30 45
	12	4 1.2	31 51
	16	13.4	+32 52

The correction of this ephemeris was very small, only +4ˢ and +2′5 for February 12. The brightness is slowly diminishing so that only larger telescopes will show the object. But it is well located in the evening sky so that it will be followed for some time. Mr. Hirose is to be congratulated on the success of his prediction which makes Periodic Comet Daniel a well-established new member of the periodic family.

Comet 1937*b* (Whipple). The first new comet this year has been announced. It was found on a photograph taken at the Harvard Observatory on February 7. It was discovered by F. L. Whipple a week after the exposure was made and the first information, broadcast on February 15, gave the following data:

1937 Feb. 7.378 U.T.: R.A. 13ʰ 19ᵐ 30ˢ; Decl. +35° 26′

Magnitude 12. Daily motion 1ᵐ 18ˢ east and 22′ north.

Nucleus and tail less than one degree.

The object was also located by the discoverer on a plate taken at the Harvard Observatory on February 4. From this information and a position obtained by Dr. Jeffers at the Lick Observatory on February 15 a first orbit computed by Whipple and Cunningham, became available as early as February 16. These first elements are:

$$\left.\begin{aligned} &\text{Perihelion passage} = 1937\ \text{June}\ 22.068\ \text{U.T.} \\ &\text{Perihelion to node} = 111^\circ\ 26'\ 57'' \\ &\text{Longitude of node} = 127\ 4\ 7 \\ &\text{Inclination} = 41\ 3\ 47 \end{aligned}\right\} 1937.0$$

$$\text{Perihelion distance} = 1.66084\ \text{astronomical units}$$

giving the ephemeris:

1937		α h m s	δ ° ′	Distance from earth	Distance from sun	Mag.
Feb.	28	13 45 17	+43 59	1.49	2.22	10.6
Mar.	4	13 49 47	45 42	1.46	2.19	10.4
	8	13 54 2	47 25	1.43	2.16	10.3
	12	13 58 2	49 6	1.40	2.13	10.1
	16	14 1 46	50 44	1.38	2.10	10.0
	20	14 5 11	52 17	1.36	2.07	9.9
	24	14 8 18	53 45	1.35	2.04	9.8
	28	14 11 6	+55 7	1.33	2.01	9.6

The magnitudes are computed assuming a value of 11.0 for February 16 and a variation according to the sixth power of the distance from the sun.

Dr. A. D. Maxwell of Ann Arbor sends the following elements, which he and Mr. Grosch have deduced from the same observations that were used by the Harvard computers:

Perihelion passage	= 1937 June 22.7709 U.T.
Perihelion to node	= 113° 08′ 08″.3
Longitude of node	= 126 44 47.4
Inclination	= 40 49 37.0
Perihelion distance	= 1.627557

The orbit is substantially the same.

The comet was found in the constellation of the Hunting Dogs and its northward motion will bring it into Ursa Major by the middle of March. It now passes overhead in the latter part of the night but can be seen toward the east before midnight. It is, however, faint and it requires a fair-sized instrument to be seen clearly. Figure 1 shows the appearance in the morning hours of February 17

FIGURE 1. COMET 1937*b* (WHIPPLE)
(Enlarged six times from an exposure on February 17, 1937, with the 24-inch reflector of the Yerkes Observatory)

when it was photographed by the writer with the 24-inch reflector of the Yerkes Observatory. The coma itself is over-exposed so that the small nucleus is not visible in it anymore. The broad tail in position angle 250° can be followed over a distance of about 12′ from the nucleus.

As indicated by the ephemeris, the distances both from the sun and from the earth are decreasing so that we may expect the comet to become brighter in the coming months. It will remain visible this spring and summer but it is doubtful if it will reach naked-eye visibility.

The other comets that have been under observation in late months are now beyond reach of almost all telescopes. The writer has not been successful so far in locating the expected periodic comets Grigg-Skjellerup, Schwassmann-Wachmann (1925 II), and Tutle-Giacobini, for which ephemerides were given in the

January issue. The first is evidently too faint yet, but should be within reach before long. The second one may brighten up any time if it shows variations in intensity similar to the fluctuations that were noticed in past years. The location of the third one is quite uncertain.

Williams Bay, Wisconsin, February 20, 1937.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The annual report of the Society is herewith presented with the understanding that it is, as often happens, not complete, due to the delays of members and regional directors in submitting their work. But it seems unwise to hold it up longer, and it may be supplemented if necessary.

The year was remarkable for unexpectedly strong Orionid and Geminid showers, while the Perseids were mediocre and the Leonids decidedly poor. This means our report no longer contains thousands of counts in November from casual observers, and as, for the first time in years, there was a slip in the newspaper publicity for the Perseids, counts in August from casual observers were also largely lacking. As our regular members become better trained, more systematic and hence more valuable work is done. The Hoffmeister-Olivier program to secure data for the problem of daily and annual variations was pushed excellently by the Missouri-S. Illinois and the Wisconsin-N. Illinois groups, the first under J. W. Simpson, the second under L. E. Armfield. Both deserve the greatest credit for their work. The latter group also determined a good number of meteor heights which they published. I understand that the large Florida group under J. H. Kusner also had considerable success in coöperative work on the fall showers. However, no exact report, even on numbers of meteors seen, is yet at hand. The other group which undertook such observations on a large scale, and with some success was the Kentucky-Tennessee. Their leadership was efficiently taken over by L. J. Wilson, as S. Bunch had moved to Oklahoma and could no longer serve. Several other groups of observers banded together for one or several nights' observations. That under J. T. Kent in Arkansas, later in Texas, deserves special mention, while the Oregon observers were individually active. As always, R. A. McIntosh reports excellent work from New Zealand. And we now have active observers in Japan and Hawaii. In India, M. A. R. Khan sends in most valuable reports on showers, and in America other observers deserve honorable mention. Their results will be found in the tables. E. Loreta in Italy continues his extremely fine work.

We have, as for years past, to thank most sincerely the U. S. Weather Bureau and the Hydrographic Office, U. S. N., for reports on fireballs, and the daily press for generous assistance in promptly publishing requests for observations of all kinds. All this assistance is invaluable. It should be added that some of the 274 fireballs mentioned in our table had from 100 to over 200 observations each, yet are listed as a single object therein. Most of these come from casual observers, due to requests for information published in the daily papers. We have certain members of the A.A.V.S.O. to thank for many of the observations of telescopic meteors. It is hard to understand why more variable star observers are not will-

ing to help out in this very easy way, which consumes practically no time nor effort.

Hoffmeister in Germany is busily reducing the tens of thousands of observations sent to him through the A.M.S. He writes me he has been making good

TABLE I[1]

Name and Station	Nights	Meteors
Anderson, Russell, Chicago, Illinois	2	22
Arslonian, L., and Stackpole, H., San Jose, Calif.	2	52
Bernhardt, Harvey, Salisbury, North Carolina	2	50[3]
Black, James L., Cleveland, Ohio	4	58
Bowman, Edward F., Kansas City, Missouri	1	174[3,2]
Braun, M. L., Salisbury, North Carolina	6	233[2]
Bugarr, G. Michael, Eugene, Oregon	1	25[3]
Bunch, Sterling, Wheatland, Oklahoma	2	28[2]
Christman, E. H., Farmingdale, New York	2	42
Dole, Robert M., Scarboro Beach, Maine	1	50
Dole, R. M., Holt, W. L., Milne, D., Scarboro, Maine	5	390[4]
Fairbrother, S. R., Chatham Islands, New Zealand	5	119
Friton, Edwin E., St. Louis, Missouri	14	206
Geddes, M., Southland, New Zealand	8	200
Gillespie, Rollin, Nitro, West Virginia	3	50[3]
Graham, Julian, Salem, Oregon	2	158[2]
Green, Gordon, Pittsfield, Massachusetts	12	247
Hand, W. E., and Knox, Reed, Jr., Cape May, N. J.	2	47
Harrell, B. L., Halcomb, G. E., Gadsden, Alabama	1	67[2]
Hunter, David, Eugene, Oregon	3	224[3]
Inouye, Hideo, Lake Suwa, Japan	12	135
Inouye, For 1935, previously unreported	3	26
Jewett, Miss Mary L., Grandview, Tennessee	11	121
Kent, Mr. and Mrs. Jack T., and three associates, College Station, Texas	5	158[4]
Kent, and Eddy, Frank, Russellville, Arkansas	9	506[4]
Khan, Mohd. A. R., Begumpet, Deccan, India	14	215[3]
Kirkpatrick, George P., New York City	13	76
Larrabee, Miss L. M., and associates, Honolulu, T. H.	2	29[3,4]
Leerman, Joseph, Baltimore, Maryland	14	187[2]
Loreta, E., Bologna, Italy	55	1438[3]
Louisville Astronomical Society, Kentucky	9	636[3]
McIntosh, R. A., Auckland, New Zealand	10	325
Marsh, Franklin F., Frederick, Maryland	1	22
Olivier, C. P., Shadwell, Albemarle County, Virginia, and Upper Darby, Pennsylvania	3	131
Parker, P. O., Cohutta, Georgia	5	191
Paterson, J. Fraser, Broken Hill, Australia	13	96[3]
Preucil, Frank, Joliet, Illinois	5	107[2]
Pruett, Hope S., Eugene, Oregon	2	233[3]
Pruett, J. Hugh, Eugene, Oregon	3	196[3]
Rhode Island Astronomical Society, Providence	1	357[3,4]
Simpson, J. Wesley, Webster Groves, Missouri	21	1149[3]
Smith, Claude H., Waterloo, New York	6	153[3]
Smith, Franklin W., Glenolden, Pennsylvania	24	220
Stone, William R., Santa Barbara, California	3	30[3]
Watson, Paul S., Sykesville, Maryland	1	20
Waugh, Albert E., Storrs, Connecticut	5	114
Whitney, Balfour S., Norman, Oklahoma	15	532
Wilson, Latimer J., Nashville, Tennessee	7	110
Wilson, R. H., Jr., Mountain Home, Kimble County, Texas	4	96
4 members reporting less than 20 each		45
		10,096

[1] Reports from members. In general, these were plotted; see notes.
[2] Count or largely count. [3] Less than half plotted. [4] Group of observers.

progress. At Flower Observatory we are pushing on the routine computations, work on several fireballs, and, most important, the research upon meteor trains. We beg all observers to send us at once any data they have on drifting meteor trains which were visible as much as one minute, or data on any train that remained visible longer, whether it drifted or not.

More people are trying the photography of meteors, and some have a certain success. I sincerely request all to send us for our files a print of each such trail, putting the known data on the back. We hear that so and so got an interesting trail, but often get no print. This does the A.M.S. no good. As we have no out-

TABLE II[1]

Name and Station	Nights	Meteors
Amateur Astronomers Association, Bethel, Connecticut	1	51[2]
Barnholth, W. I., Akron, Ohio	1	35
Blakeslee, Howard W., Lake Kezar, Maine	1	150
Brady, James F., Webster Groves, Missouri	12	590
Brooks, Miss B., Silver Lakes, New Hampshire	3	61
Brooks, Miss E. H., Silver Lake, New Hampshire	1	21
Brooks, Edward M., Silver Lake, New Hampshire	6	101
Claridge, Elmond L., Webster Groves, Missouri	15	333
Curtis, Clayton, Pittsfield, Massachusetts	1	26
Daub, Harrison	1	43
Ellison, Miss Mary, Webster Groves, Missouri	32	832
Fentress, George H., Nashville, Tennessee	6	65[3]
Hampton, S. D., Auburn, Alabama	1	69
Hickerson, J. Fletcher, Webster Groves, Missouri	13	172
Joliet Astronomical Society, Joliet, Illinois	1	78
Komaki, Mr. and Mrs. Koziro and Miss Kanaya Aritagun, Wakayamaken, Japan	25	888[3]
Lambert, George E., Dunlo, Pennsylvania	6	230[2]
Milwaukee Astronomical Society and coöperating observers, Wisconsin	(570 hr.)	2864
Missouri-S. Illinois Observers	(less than 10 nights each)	1117
Oregon Group, 6 observers	14	618
Reid, Alfred G., and students of Pennsylvania Academy of Fine Arts, Chester Springs, Pennsylvania	1	354
Richter, Kenneth, and Cox, A. E. 3rd, Bridgewater, Mass.	4	476
Senne, Joe H. Jr., Webster Groves, Missouri	17	255
Simpson, A. M., Webster Groves, Missouri	2	1036
Truxton, Joseph D. Jr., Philadelphia, Pennsylvania	3	177
Zahner, Don D., Webster Groves, Missouri	10	364
6 observers reporting less than 20 each		52
		11,058

TELESCOPIC METEORS

Ashbrook, Jos., Philadelphia, Pa., Holderness, N. H., and Baltimore, Maryland	13
Chandra, R. G., Jessore, India	9
Cook, Allan Fairchild II, Westfield, New Jersey	7
Flower Observatory, Upper Darby, Pennsylvania	48
Freeman, H. L., Washington, Illinois	1
Inouye, Hideo, Atsuta, Nagoya, Japan	79
Jones, Eugene H., Goffstown, New Hampshire	28
Kirkpatrick, George P., New York City	43
Loreta, E., Bologna, Italy	4
Meyer, Irving L., Rutherford, New Jersey	1
Rosebrugh, D. W., Poughkeepsie, New York	6
	239

[1] Reports from non-members. In general these were not plotted; see notes.
[2] Plotted. [3] Three-fourths plotted.

side funds this year, members who can do so, and have not, are asked to send in their annual dues.

It will be seen that our totals for this year are larger than for 1935, due to better showers and better weather. Some meteors not in the 1935 report are found belatedly in this one. A very large part of the meteors appearing in Table II are timed counts for the Hoffmeister-Olivier program. However, some of the observers sent in plotted paths, possibly 10% to 20% of the whole.

PHOTOGRAPHIC METEORS

Arslonian, Leon, San Jose, California	3
Christman, E. H., Farmingale, New York	1
Mr. Cook's Observatory, Wynnewood, Pennsylvania	1
Dole, R. M., Scarboro, Maine	2
Wilson, Latimer J., Nashville, Tennessee	1
	8

SUMMARY

Table I	10,096
Table II	11,058
Telescopic Meteors	239
Photographic Meteors	8
Fireballs	274
Grand Total for 1936	21,675

Flower Observatory of the University of Pennsylvania,
Upper Darby, Pennsylvania, 1937 February 22.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD, President, *and* H. H. NININGER, Secretary

The Determination of Meteor Velocities*

By WALTER T. WHITNEY

Much of the interpretation of the data obtained in meteor observations depends ultimately upon the accuracy with which the meteor's velocity can be established. In this paper we wish to report upon some new experiments in meteor photography which promise an increased precision in the determination of meteor velocities. To determine a meteor's velocity, it is necessary to find the actual position of the body's observable track in the earth's atmosphere, and hence the real length of the track, as well as the time the meteor took to traverse this distance. The only available method for determining this space position depends upon simultaneous observations of the same meteor's flight from two or more suitably separated stations. Visual observations, using the star background for reference, even with the employment of visible reticles of wires or rods, or oscillating mirrors, leave much to be desired in the matter of precision, although the recently increased use of reticles in this work has greatly enlarged the mass of collected data from which statistical studies can be made. The more exact determination of a meteor's velocity must rest, therefore, upon photographic observa-

*The revision of a paper read at the Fourth Annual Meeting of the Society, University of California at Los Angeles, June 23 and 24, 1936; the illustrations showed are not reproduced here.

[The term *meteor* is used in this paper in the sense of an ***incandescent meteorite in flight*** in the earth's atmosphere.—ED.]

tions. Occasionally a meteor provides a burst or an explosion at some point, or, better still, at several points along its incandescent flight. These bursts provide simultaneously marked spots which appear in each photograph at the separated observing stations. The positions of these marked spots are carefully measured with reference to the background of stars, which also will have been photographed upon the same plates. Differences in the apparent position (*i.e.* the parallax), of the meteor's train, with respect to this background of stars, are caused obviously by the different points of view of the various photographing cameras, since the meteor is relatively close at hand, while the stars are virtually infinitely more distant. Stations separated by from 25 to 50 miles serve nicely for such experiments. Most meteor trails, however, lack any such distinguishing marks as described and present a smooth streak upon the photographic plate, upon which even the terminal points are decidedly indefinite. Furthermore, many factors operate to create differences between the sensitivity of the photographic equipment at the different observing stations, thereby introducing errors in the result, for which little, if any, allowance can be made. It may be appropriately urged at this place that many so-called amateur or hobby astronomers are already well equipped to obtain valuable results by photographing meteors in coöperation with others, if they chance to possess a good camera with a lens whose aperture ratio is about *F*. 4½ and which has a focal length of several inches. Such an equipment is far from uncommon; moreover, it is quite impossible to overcrowd the field with observers, since any one observer sees meteors from only a small part of the earth's atmosphere.

Assuming, then, that the space position of the meteor's photographed trail has been determined, what of the velocity with which it traced this path, or the variation in this velocity, due to the air friction which gave rise to its luminosity? For the timing of meteors, the employment of a rotating shutter placed before the lens of the camera is not a new plan. This shutter is arranged to spin steadily at such a speed that the lens is alternately covered and exposed from 15 to 25 or more times per second. A meteor's trail is thus photographed as a series of dashes whose duration can be exactly timed, since the speed of the shutter blades is known and held constant, usually by means of a synchronous electric motor. Determination of the meteor's actual velocity, then, becomes a matter of simple arithmetic, since the true length of its trail has been computed. Such a rotating device mounted on but one of the cameras in a coöperative experiment, will serve to establish the meteor's velocity only when the determination of the length of the meteor's trail is accurate. But, as explained previously, few meteors provide any really definite points along their tracks suitable for accurate measurement; hence, some attempts at the measurement of pairs of meteor-trail photographs, where only one was taken through a rotating shutter, served to demonstrate mainly the inaccuracies of the results obtained and to suggest the sources of error. To overcome these difficulties and to improve the existing methods of determining meteor velocities, it was proposed that both cameras of a two-station set-up should be equipped with identical rotating shutters, to be maintained in synchronism and in exactly the same orientation with their respective lenses by means of automatic radio control. With synchronized shutters on both cameras, it is clear also that even if the meteor failed to show any bursts or other distinguishing marks along its track, the shutter interruptions would automatically provide not one but several simultaneously marked points suitable for fine measurement. These would make possible also a more precise computation of the meteor's position in space and the length of its path, upon which the subsequent results depend. Accordingly, through

the courtesy of the Mt. Wilson Observatory of the Carnegie Institution of Washington, at Pasadena, California, it became possible at the time of the Perseids of August, 1935, to make a trial of this plan for the first time, between the Observatory on top of Mt. Wilson and the Frank P. Brackett Observatory of Pomona College at Claremont. Unfavorable weather conditions conspired with the moonlight, so that no meteor-trail photographs were obtained at the time of this initial experiment, but the technical phases of the project had been tested and proved to be most promising. Accordingly, in the following August (1936), the experiments were repeated with improved mechanical and electrical apparatus and with more powerful optical equipment as well. The latter included one of the new-type Schmidt reflector cameras, together with fast camera lenses of the usual type.

The original plans for the 1936 experiment contemplated the location of the observing stations, one at the Mt. Wilson Observatory and the other at the Smithsonian Solar Radiation Observatory on Table Mountain. The separation of these two points is about 25 miles and both are at high altitudes; but, on account of the idiosyncrasies of five-meter-wave-radio transmission in mountainous regions, it proved impossible to establish adequate communication between these points. Therefore, since we were restricted to five meters by radio-license considerations, and strong radio signals between stations were a vital part of the project, it became necessary to abandon the Mt. Wilson location (elevation nearly 5900 feet). The Table Mountain station, however, at an altitude of 7400 feet, was eventually operated in conjunction with another, 35 miles to the *east*, at Green Valley Lake, at an elevation of 7200 feet. This pair of stations proved ideal from every point of view. The weather conditions on the two nights during which observations were conducted likewise proved ideal, and, in spite of the limitations of a camera field, only 10° in diameter, a portion of one meteor trail was obtained simultaneously from both stations. Numerical results from the computations, based upon the data thus afforded, are not as yet entirely available, so that this report concerns itself principally with the establishment of what appears to be an improved method of obtaining quantitative meteor-velocity measures.

The principal point of difference between these observations and others employing meteor cameras placed behind rotating shutters, lies in the fact that *both* of our cameras were equipped with identical shutters, kept in precise synchronism with each other by means of a radio stroboscopic signal transmitted from one shutter to the other. The advantages which result from such a plan have already been emphasized, but a few words in description of the actual arrangement would seem to be in order. The rotating fan-like shutters were driven by one-fifteenth horse-power synchronous motors operating from the power lines of the Southern California Edison Company, which supplied both locations. In this way, it was found that when once placed in step by means of the radio linkage, the two shutters remained in absolute synchronism during hour after hour of continuous operation. The interruptions effected by the rotating blades of the shutters occurred at the rate of twenty per second. Alternate blades were of two different widths; hence interruptions of two different lengths alternated with each other along the photograph of the meteor's train, to facilitate the identification of coincident points when the simultaneous photographs from the two stations were compared. The shutters were cut from duralumin sheet so that a continuous circular rim surrounded the blades. In this rim a narrow radial slit was cut, upon which the image of a small concentrated filament lamp was projected by a short-focus lens. Behind this slit a photoelectric cell was located which was connected to the output of the radio transmitter. Thus, a very brief signal was broadcast once in each

revolution of the transmitting shutter. This signal was received at the other station, and, after amplification was impressed directly upon a small filament neon bulb. This bulb was placed a few inches behind the circular ring of the receiving shutter in which also a radial slit was placed in an exactly similar position to the one in the transmitting shutter. A stationary sighting slit was mounted a little way in front of the receiving shutter and opposite to the neon bulb. Thus, when the bulb, the shutter slit, and the sighting slit were in line, and the image of the source light was upon the slit of the transmitting shutter, both rotating shutters had exactly the same position in relation to their respective camera lenses. With the receiving shutter in rapid rotation, it is clear that the neon bulb, being viewed through the two slits, could be seen to flash only in response to the radio signal, if the two shutters were exactly in step with each other at every revolution and remained so.

The complete success of this project for the remote radio control of synchronization was very gratifying. I am pleased to acknowledge the collaboration and courtesies of many persons. Mr. Albert K. Edgerton, Mr. John S. Hopkins, and Mr. Frank Loney, former students in the Department of Astronomy of Pomona College, have rendered invaluable aid in the matters of radio engineering, of construction, and operation throughout these experiments. I am very grateful also to Dr. H. P. Bailey of Riverside, California, for the loan of his fine Schmidt reflecting camera, and to Dr. W. S. Adams, Director of the Mt. Wilson Observatory, and to Mr. Hoover of the Table Mountain Observatory of the Smithsonian Institution, who gave permission to establish the meteor stations on their grounds. I hope that the description of these experiments may incite the collaboration of many radio and astronomical enthusiasts, whether amateur or otherwise. The study of meteorites, whether in the air as meteors or after their arrival on the surface of the earth, is not by any means complete; hence, contributing observations, from all possible sources, are seriously needed.

Frank P. Brackett Observatory, Pomona College, Claremont, California,
1937 January

Some Remarks on the Physical Problems Involved in the Crystallization of Iron in a Graphitic Matrix in Meteoritic Material*

By L. F. Brady

Abstract

The speaker commented on problems connected with the thermal history of meteorites, on which light might be thrown by a study of the graphitic inclusions found in some irons. In particular, in the Elden, Arizona, meteorite, which is probably an unusually large inclusion of a Canyon Diablo iron, part of the iron appears to have crystallized in a matrix of carbon.

A study of the behavior of iron-carbon mixtures at high temperatures and low pressures might give some clue to the problem.

Mesa Ranch School, Mesa, and Museum of Northern Arizona, Flagstaff, Arizona

*A paper delivered at the Fourth Annual Meeting.

Secretary's Office: Nininger Laboratory, 1955 Fairfax Street, Denver, Colorado
Editorial Office: Department of Astronomy, University of California at Los Angeles

The Composition of Meteors

By JOHN DAVIS BUDDHUE

Since meteors never reach the ground there is no direct method of determining their composition. There are, however, several indirect methods which can be used, though some are based on assumptions which are open to question. These methods might be listed as follows:

1. The spectra of comets.
2. The composition of meteoritic dust.
3. The probable relationship to meteorites.
4. The spectra of meteors themselves.

The first of these rests on the assupmtion that meteors and comets are at least intimately connected and perhaps are manifestations of the same thing under different conditions. This, of course, cannot be proved, but it is supported by the fact that the elements of the orbits of several meteor streams correspond within very small limits to the elements of known comets. In some cases these comets have disintegrated and the meteors still occupy their orbit. Thus the Perseids and Comet 1862 III have similar elements, the Leonids and Comet 1866 I have almost identical elements and the same may be said of the Draconids and Comet Giacobini-Zinner (P. A., XLII (1934), 509). The only logical deduction from this is that either the meteors are the comet, or that they are a notable part of it. This being so, it is only reasonable to suspect that the composition of comets as revealed by their spectra might be applied to meteors.

The spectra of comets is in most cases a combination of two spectra. One is faint and continuous, and probably arises from the reflection of sunlight from the material of the comet, and the other consists of bright lines. The latter are of unknown origin but it is suspected that they are fluorescent. That is, certain specific frequencies are absorbed from sunlight and then re-radiated. Thus sodium might absorb the two frequencies which correspond to the D lines and become ionized in the process. Then when the atom is neutralized the same frequency is emitted again and appears as a bright line in the spectrum.

The spectra of most comets consist of three characteristic bands due to carbon. With these may appear other lines due to the oxides of carbon, to cyanogen, to sodium, and in one case to iron though this is somewhat doubtful. Thus the spectra of comets reveal the presence of carbon, nitrogen, oxygen, sodium, and probably iron and hydrogen. The presence of the last element is inferred from the three characteristic bands which seem to be due to carbon in the form of hydrocarbons, probably methane. It is worthy of note that the gases derived from meteorites by heat can be made to emit spectra closely resembling the spectra of comets.

The composition of meteoritic dust should reveal much information in regard to the composition of meteors. The difficulty is in obtaining authentic meteoritic dust in quantities sufficient for analysis. To the best of my knowledge this has not been done. However, the Challenger expedition found magnetic spherules of two types in the specimens dredged up from the sea bottom (Challenger Report, pp. 327-336).

In one case they consisted of small, black, spherical bodies, rarely exceeding 0.2 mm in diameter. The surfaces were black and shining with a metallic luster and contained numerous minute pores. In almost all cases there was a small

cupule or depression on one side, which sometimes attained a diameter approaching half the diameter of the spherule. Examination of these tiny objects shows that they consist of a black crust of magnetic iron oxide covering a core of metallic iron. This can be seen by crushing the spherules in a mortar which breaks away the crust and leaves the iron core which is of a grey color and malleable. Usually it gives reactions suggestive of iron such as the precipitation of metallic copper from solutions of its salts. In cases when it does not, it is supposed that the core is composed of schreibersite or an alloy of iron, cobalt, and nickel which under certain conditions will not precipitate copper.

The other type is yellowish or brownish in color, with a metallic luster due to a finely laminated structure. The surfaces are striated, and the cupule, when present, is not deep. On the whole they are larger than the type described above as they average around 0.5 mm in diameter and rarely exceed 1 mm. Their structure is closely analogous to that of certain kinds of chondrules found in meteorites.

Complete chemical analyses of these are not available, but the black spherules certainly contain iron and cobalt, and the brown type contain silicon, magnesium, and iron. From their optical properties they approach the orthorhombic pyroxenes in composition.

From their appearance these spherules are composed of particles torn off of meteors during their incandescent flight through the atmosphere. Being liquid they would tend to assume a spherical form while the attendant contraction might easily form the cupule. They are most abundant in the deeper parts of the ocean's floor where there is the least tendency for other material to accumulate. It is said that a quart of red clay will yield twenty to thirty black spherules and five or six brown ones and both will be mixed with a much larger quantity of magnetite of undoubted terrestrial origin.

Nordenskjöld collected so called meteoritic dust in Greenland in 1870 and in 1883. This was examined by Wülfing (*Neues Jahrb., Beilcgeband* VII, 1890, 152) who found that it was composed mostly of terrestrial minerals and organic matter of humic nature. He also found rare magnetic spherules from 0.09 to 0.17 mm in diameter. None of these had metallic nuclei. Some were transparent and some opaque. Polarized light showed that some were isotropic, and others were birefringent. The opaque ones were black, and appeared to be magnetite.

Hence, in so-called meteoritic dust we find iron, cobalt, magnesium, and silicon but we cannot be certain that the dust is meteoritic nor do we know what other constituents may be present.

It seems more than likely that meteors and meteorites differ only in point of size, the latter being large enough to reach the surface of the earth before they are completely disintegrated. However, there are objections to this theory. Among them is the fact that no meteorite can be assigned positively to a meteor shower.

The Mazapil iron may be an exception to this as it fell on November 27, 1885, during a shower of meteors. Consequently it may be an Andromedid. Another suspected case is the Rowton, England, iron which fell April 20, 1876. It may therefore be a Lyrid. Analyses follow:

	Rowton	Mazapil	
Iron	91.250	91.260	
Nickel	8.582	7.845	
Cobalt	0.371	0.653	
Copper	tr	(0.300 = phosphorous)	
	100.203	100.058	

The Rowton mass also contained sulphur as troilite and 6.38 times its bulk of gas (Flight, *History of Meteorites,* 1887, p. 194) which contained the following:

$\%CO_2$	%CO	%H	%N
5.155	7.345	77.778	9.722 = 99.990

Other meteorites have fallen on dates corresponding to those of meteor showers, but there seems to be no good reason to believe that they were members of the shower.

Assuming that meteorites do not differ from meteors in any important manner except size we find that all known elements with few exceptions (notably the rare gases) are found in them although only a few are important (von Hevesy, *Chemical Analysis by X-Rays and its Applications*). Taking meteorites as a whole Farrington (*Meteorites,* 1915, p. 216) lists iron, silicon, nickel, and magnesium as the only ones occurring in amounts exceeding one per cent. Aluminium, calcium, sulphur, sodium, phosphorous, and chromium all occur in amounts exceeding 0.1 per cent or only slightly less. The rest of the elements make up only 0.16 per cent.

The most reliable information we have regarding the composition of meteors is afforded by the few spectra which have been secured. Such information might almost be regarded as direct.

The earliest attempts to observe the spectra of meteors were necessarily visual because photography, if it existed at all, was not yet capable of making pictures of such faint phenomena as meteor spectra. These early results frequently showed the presence of a bright line in the yellow which was interpreted as sodium. Some meteors, especially the green ones, showed the presence of magnesium, or at least a line where the green magnesium line ought to be. Certain lines in the red were interpreted as due to lithium. Lines in the position of H and K were attributed to calcium and other lines were supposed to be due to copper, potassium, thallium, hydrogen, helium, and methane. Of these, I think, we can be sure of only the magnesium lines; the sodium lines, the calcium lines, and probably the "copper lines" were due to iron. Although sodium forms only about 0.17 per cent of meteorites the D line is extremely sensitive and easily recognized, and for that reason I accept its visual determination.

Of late years photographs have been secured, and nine of these are discussed in one of the Harvard publications (*Harvard Annals,* Vol. 82, No. 6). The first one was secured by accident while photographing stellar spectra with an objective prism at the Arequipa Observatory of Harvard. Six lines appeared which were partly identified by Pickering as due to the Balmer series of hydrogen. Later they were all shown to be due to iron.

Blajko of Moscow secured three spectra. One was not reported in the literature but the other two were. In one he identified certain of the seventeen lines as due to calcium (H and K = Ca^+ and also Ca°) magnesium and potassium. The other had thirteen lines of which five were supposed to be due to helium and one to thallium. The unreported spectrum contained twenty-one lines among which only H and K were identified.

The next spectrum was secured at Harvard and contained fifty-three lines which will be discussed later.

Two spectra were discovered on plates taken at the Mount Wilson Observatory, one containing thirty-one and the other twenty-eight lines. Neither was investigated.

Schwassmann in Germany secured a thirteen-line spectrum, two of the lines he attributed to ionized calcium and the remainder to iron.

The last spectrum contained forty-two lines.

Identification of the lines in meteor spectra is rendered difficult by the small resolving power of the spectroscopes which must necessarily be used. However, all the plates were calibrated by Millman of Harvard by various methods with the results given in the table. The work was rendered difficult by the fact that some

Spectrum	Lines	Identifications
I	6	All due to iron.
II	17	10 due to iron, 1 due to calcium, 2 due to aluminium, 1 due to iron or magnesium, 2 due to iron or manganese, 1 due to ionized calcium.
III	13	11 due to iron, 1 due to iron or magnesium, 1 due to iron or ionized calcium.
IV	21	18 due to iron, 1 due to ionized calcium, 1 due to neutral calcium.
V	53	44 due to iron, 1 due to silicon, 1 due to iron or silicon, 2 due to manganese, 1 due to iron or manganese, 3 due to chromium, 1 due to iron or chromium.
VI	31	21 due to iron, 9 due to magnesium, 2 due to aluminium, 1 due to manganese, 2 due to neutral calcium, 1 due to ionized calcium, and 2 unidentified.
VII	28	27 due to iron, 1 due to iron or manganese.
VIII	13	12 due to iron, 1 due to ionized calcium.
IX	42	31 due to iron, 1 due to silicon or iron, 1 due to silicon, 3 due to manganese, 5 due to neutral calcium, 1 due to ionized calcium.

of the lines were blends of two or more lines which were not necessarily due to the same element. It is worthy of note that sodium does not appear in any of the identifications.

Three of the meteors were Perseids, numbers III, IV, and VI, and it is an interesting fact that there is no particular correlation between them although they belong to the same stream.

From the available data it appears, therefore, that we can be certain that the following elements occur in meteors: Iron, Magnesium, Calcium, Manganese, Silicon, Chromium, and Aluminium.

The following almost certainly occur: Cobalt, Sodium, Nickel, Carbon, Hydrogen, Oxygen, Nitrogen, and Sulphur.

The actual combinations in which these elements occur is, of course, difficult to say but from the evidence of magnetic spherules from the ocean bottom it would seem that we could expect the usual alloys of iron and nickel, and pyroxene minerals and perhaps schreibersite. The spectra indicate the possibility of feldspars and chromite and perhaps chrysolite and daubreelite. If they are similar to meteorites all of these and several more are doubtless present.

In closing I wish to state that this paper is not intended to cover the whole field nor is it intended to be final. My intention is rather to collect in one spot the information which seemed significant to me, in other words it is an introduction to the subject.

94 South Raymond Avenue, Pasadena, California.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editors may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

Agglutination and Gravitation

It is a far call from bacteriology to astronomy, yet a phenomenon observed in any branch of science may sometimes throw light on some problem of a totally separate branch. The writer's knowledge of astronomy and physics is meager, about that of the average amateur telescope maker, but he is well trained in bacteriology. It is the purpose of this article to point out certain similarities between bacterial agglutination, one of the commonest phenomena in bacteriology, and gravitation, in the hope that it may be of some interest to astronomers, whose training may naturally not have embraced bacteriology, and it is hoped that it will not be thought presumptive for one with no special knowledge of the natural sciences to theorize on gravitation.

For a common example of agglutination let us take the bacillus of typhoid fever. This bacillus is a short rod, about two microns long, with numerous flagella, or hairlike organs of motility, growing out in all directions. If we look through the microscope at a drop of broth containing these live bacilli, we see only the rods or "bodies." To bring to sight the flagella, the germ must be killed and stained. What is actually seen in the drop containing the live organisms is innumerable little rods in extremely active motion, darting every which-way all over the field. Now if we add to the drop of broth a drop of highly diluted blood serum from a person with typhoid fever, the bacilli are slowly killed. There is some element in the blood serum, some anti-body, fatal to the germs.

As the bacilli are thus slowly killed, they "agglutinate." They form in little groups of a few dead or sluggish bacilli, surrounded by the still active, live, germs, for some of the bacilli are more vital, and die slower than others. Gradually these little clusters form into larger groups, so that in the end we may have only one or two large spherical clusters, containing thousands of dead or dying bacilli, in an entire microscopic field, with a few still active bacilli between the groups.

It is obvious that if we have two dead, and hence non-motile, bacilli fairly close to each other, say ten microns apart, and surrounded on all sides by active live, bacilli, which are continually striking them, each non-motile bacillus will be struck more often on the side farthest away from the other non-motile bacillus, merely because these sides are more exposed to the buffeting, and hence the two non-motile germs will be pushed together. These little groups of two or three will in turn be forced together to form larger groups.

This is a simple mechanical explanation of agglutination. The writer is thoroughly familiar with the fact that other elements enter. For instance there is a mysterious agent called "agglutinin," which is in the immune blood serum, and seems to act independently of other bactericidal agents. Also it is claimed that agglutination may be obtained, or partially obtained, in dead cultures, under certain conditions. Nevertheless, the simple mechanics, described above, must play a prominent part in agglutination, at least with motile bacilli.

If we conceive of the universe as composed of molecules, we may compare the

bacilli to these molecules, and their movement to inter-molecular (not intra-molecular) motion. In that case the molecules of the ether of space could be compared to the still active, live, bacilli of the agglutination phenomenon, and the visible, palpable, matter of which the stars, etc., are composed, could be compared to the dead, agglutinated, germs. This is the theory here offered. By it, gravitation would be molecular inactive substance, or matter, being agglutinated or pushed together by molecular active substance, or ether. Of course, it is known that the ether permeates all matter to some extent, but that offers no contradiction.

At any rate is there any way, other than by means of bacteria, to obtain an approximation of intermolecular activity? The movements of the bacilli are caused by energy within themselves, and are every which-way. Also the number that may be seen at any one time is enough to show the results of their movements on the entire mass. This first necessity, that of a source of movement within the individual units, can hardly be obtained by any other means.

So the theory of gravitation offered at least has the advantage of some slight experimental background, vague and imperfect and doubtful though the comparison be. But what other theory has even that? Also it is in line with other natural phenomena easily grasped by the human mind. To imagine an "attraction" by some intangible bond called gravity, we must think of this bond as something that may be stretched from a micron, or less, up to many light years. It is hard for the mind to accept such an idea, much more so than to think of gravity as a push by an intangible force.

The theory, of course, accepts the old, disputed "ether," and all that goes with it, such as the undulatory theory of light, but I believe the quantum idea has not entirely discredited the ether yet.

WILLIAM E. GLANVILLE.

176 Herrick Road, Southampton, New York.

Notes from Amateurs

Amateur Astronomical Society of New Haven

The "Amateur Astronomical Society of New Haven" was organized January 9, 1937, in the home of Mr. D. S. Kimball, 156 Maple Street, with a charter list of fourteen enthusiastic members. Mr. Kimball was elected President and F. R. Burnham, 820 Townsend Avenue, Secretary. The Association held one more meeting on January 16 at the home of the President and on Saturday evening, February 20, held its first meeting in the Lecture Room of the Yale Astronomical Building which will be our future meeting place, with an attendance of twenty-two, and several applications for membership were received.

Mr. James Neale, one of our members, gave a very interesting talk on "Amateur Telescope Making" explaining many points by means of black-board sketches. He explained fully the various stages in grinding, polishing, and figuring a mirror for a reflecting telescope, and had several mirrors in various stages of operation as exhibits, and demonstrated the use of the Foucault Shadow test upon several of them which were incorrectly figured. He also showed a Springfield mounting in an advanced stage of completion.

The interest of our present membership is naturally varied, six of the group are now making 6-inch reflectors, one is making observations of occultations of the moon, one has considerable experience in observing meteors, and three are particularly interested in reducing occultations. The prospects of the future of

the society are very promising. The next meeting of the group will be held on March 20 in the Observatory Lecture Room.

F. R. BURNHAM, *Secretary.*

Amateur Astronomers Association of Pittsburgh, Pennsylvania

The *Bulletin Index,* Pittsburgh's Weekly Newsmagazine, issue of recent date carries a two-page boost for local amateurs. Smoky Pittsburgh, paradoxically, has the largest group of amateur astronomers in the United States. The brothers Scanlon and their Valley View Observatory have just had the 1400th name placed in their guest book.

Under the heading of "Science" the *Bulletin Index* also publishes a picture of Secretary Scanlon and President Weisiger and Treasurer Goin with their home constructed telescopes.

Four persons attended the first meeting; sixty swarmed to the last, a fortnight ago to hear member Charles Skeele Palmer, retired professor of chemistry from Denver University, speak on the "Chemistry of the Stars."

Boasting a roster of some 150, more than 50 have built or are building telescopes. The rest are keenly interested in astronomy and attend the lectures.

Secretary Scanlon has the finest private observatory in the district. His telescope is equipped with a camera, is of the reflecting type with a 10-inch mirror but will soon have a larger one. The 12-foot dome on the observatory is sheet aluminum, self-supporting, the only one of its kind ever built.

14 Lincoln Drive, Cleveland, Ohio. DON H. JOHNSTON.

General Notes

Dr. Roy K. Marshall, professor of astronomy at Wilson College, Chambersburg, Pennsylvania, gave an illustrated lecture on general astronomy at Dickinson College, Carlisle, Pennsylvania, on Sunday, February 7, 1937.

Dr. Robert Grant Aitken, emeritus director of Lick Observatory in California and holder of numerous honors in the field of astronomy, will speak on the subject of "Driving Back the Dark," on the evening of March 17, at Mills College, Oakland, California, the second oldest college for women in America, in connection with the celebration of the eighty-fifth anniversary of its founding.

Dr. Aitken is noted for the discovery of 3100 double stars since 1899. In 1906 he was awarded the Lalande Prize for his discoveries in this field; and since then he has been awarded the Bruce Gold Medal for distinguished service to astronomy, and the Gold Medal of the Royal Astronomical Society. In 1908 he was a member of the Lick Observatory Eclipse Expedition to Flint Island. Dr. Aitken has also gained renown as an editor and author in the astronomical field.

The Fels Planetarium of the Franklin Institute of Philadelphia is being used this season for demonstrations in connection with a course of lectures on navigation, given by Lt. Com. P. V. H. Weems, U. S. Navy, Retired, head of the Weems system of navigation and author of textbooks in this field. Since navigation now applies not only to ocean travel but to aerial travel as well, it has a new significance and interest. The lectures began on January 19 and will be continued on each Tuesday evening throughout a series of twenty-one.

The Rittenhouse Astronomical Society of Philadelphia held a meeting on Friday, February 12, in the Hall of The Franklin Institute. After the usual dinner, the program consisted of an address on the subject, "Photographing the Nebulae from Mount Wilson," by Dr. John C. Duncan, Director of the Whitin Observatory, Wellesley College, Research Associate, The Mount Wilson Observatory, Secretary, The American Astronomical Society.

The Daytona Beach (Florida) Star Gazers are continuing their schedule of bi-weekly meetings which was inaugurated seven years ago. At present they have reached the point of having a 12½-inch mirror in the process of construction. This group of amateurs feel that the unusually favorable climate will make it possible to use a telescope of this size to very good advantage. The new instrument will need housing and this will stimulate the construction of a permanent building which will still further accentuate the interest in astronomical study. This telescope is to be known as the William Tyler Olcott Memorial Telescope.

Mrs. G. M. Randall, P. O. Box 5156, Daytona Beach, Florida, is the secretary of this organization.

Some Forgotten Astronomers

In the *Memorie della Societa-Astronomica Italiana,* Vol. X, No. 2 (1937), Professor Pio Emanuelli has published an historical paper on some forgotten astronomers, *i.e.* astronomers concerning whom no biographical data may be found in the astronomical literature. The astronomers considered by the author are twelve in number: nine Italians, *viz.,* C. Palomba (1819-1891), T. Cugnoni (1822-1903), G. Santarelli (about the middle of the XIX century), L. Del Re (1805-1872), A. Nobile (1794-1863), G. Gobbi-Beleredi (1820-1899), G. Pinali (1780-1840), C. A. Manzini (1599-1677), G. Sirsale S. J. (1584-1654); one French, J. Richaud S. J. (1633-1693); one German, G. Schönberger S. J. (1597-1645); and one Danish, G. Sarcerides (1562-1612) a pupil of Tycho Brahe.

The German, Father George Schönberger, a Jesuit, was author of a curious treatise, published in 1626, about the strange theory on the liquid nature of the heavens, advocated by him in opposition to the old theory of the solid heavens. For this theory, Father Schönberger was censured by the authorities of Rome, on instigation of some adherents to Aristotle's views on solid heavens.

Professor Emanuelli recommended the proposal for a great biographical Astronomical Dictionary of all the astronomers, from the most ancient time down to the present. A first step in this direciton may be made with a collection of some national biographical Astronomical Dictionaries (American, English, French, German, Italian, etc.) compiled by astronomers of the same nationality as those that are listed.

The Lamont-Hussey Observatory

The Lamont-Hussey Observatory, a branch of the Observatory of the University of Michigan, was established in 1926 at Bloemfontein, Orange Free State, South Africa, through funds supplied by the Hon. Robert P. Lamont, an alumnus of the University and a life-long friend of Professor Hussey. Equipped with a 27.5 inch refractor of unusual excellence, the purpose of this Expedition was to extend to the southern skies the systematic search for double stars inaugurated by Dr. Aitken and Dr. Hussey many years earlier at Lick Observatory. This southern station has been in charge of Dr. Richard A. Rossiter, assisted for several years

by Henry F. Donner and Morris K. Jessup. Over 5,500 new double stars have been discovered to date in this program,—a contribution of great value to statistical and double star astronomy.

It had been feared that the failure of financial support would necessitate the closing of this southern station next July. It is a pleasure now to state that the work of the Lamont-Hussey Observatory will be continued for five more years through the generous action of the Union of South Africa and the Municipality of Bloemfontein. It would be difficult to frame an agreement marked by greater liberality or by a more genuine scientific spirit than the one that has been proffered by the Union of South Africa jointly with the Municipality of Bloemfontein. The University of Michigan is asked to leave its telescope and plant *in situ* for the coming five years, while South Africa furnishes the support. The South African authorities desire to specify that no change whatever is to be made in Dr. Rossiter's program of research; he will thus be enabled to make certain areas of the double star discovery survey more complete and, in particular, to re-measure and establish accurate initial positions for the many close and interesting pairs that have been discovered.

Summary of Sun-Spot Observations at Mount Holyoke College, 1936

Month	No. of Obs.	North of Equator No. of Groups	North of Equator Av. Lat.	South of Equator No. of Groups	South of Equator Av. Lat.	Av. No. groups at one Obs.	New Groups
January	22	8	+19°.1	14	−20°.0	4.73	22
February	14	15	19.1	17	17.8	5.86	28
March	6	7	21.4	10	20.4	5.83	14
April	15	13	20.6	18	20.2	5.80	31
May	20	11	20.9	14	18.5	4.05	24
June	17	13	21.9	10	20.2	4.53	21
September	6	8	18.2	7	21.9	7.33	15
October	14	12	17.1	19	18.3	6.93	27
November	17	11	17.1	23	15.9	6.94	30
December	10	10	17.3	12	18.2	6.20	13
Totals	141	108		144			225
	Average number at one observation					5.82	
	Average latitude of spots north of equator					+19°.5	
	Average latitude of spots south of equator					−19°.3	

The total number of observations is smaller than in recent years because none were made during the college vacations. Miss Helen Porter made most of the observations.

On no day was the sun free from spots.

The greater activity in the southern hemisphere shown in the previous report was accentuated during this past year. The average number at one observation is distinctly larger than at the corresponding phase in three previous cycles.

ALICE H. FARNSWORTH.

John Payson Williston Observatory.